AIPS Memo 114

The FITS Interferometry Data Interchange Convention — Revised

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Contents

Abstract

The FITS Interferometry Data Interchange Convention ("FITS-IDI") is a set of conventions layered upon the standard FITS format to assist in the interchange of data recorded by interferometric telescopes, particularly at radio frequencies and very long baselines. It is in use for the VLBA telescope for data from the current hardware correlator and the future software correlator and has also been used with other correlators such as the JIVE correlator for the EVN. This convention is intended to separate a standard set of conventions from those used within particular software packages such as $\mathcal{AIPS}$.

1 Preface

The original proposal for the FITS Interferometry Data Interchange Convention ("FITS-IDI") was made in 1997 by Diamond, et al. [1]. The format actually adopted by the VLBA Correlator differed from this proposal in a number of ways, causing Flatters[2] to re-draft the proposal in late 1998. Unfortunately, the text file from which this beautifully formatted PostScript document was produced has been lost, which means that it is unable to be revised. This Memo is therefore, initially, a transcription of [2] without the beautiful formatting. It will then be revised as required to add new capabilities and to clarify the text. Corrections and other basic additions are shown in red. Specific additions to the Convention made during the IAU FITS Working Committee comment period are present in blue.

The FITS format was initially defined in a series of published papers, but has been revisited by standards committees. The official, IAU-adopted version 3.0 of the fits standard [3] and a large amount of supporting documentation may be found at the web site `http://fits.gsfc.nasa.gov/`. All papers defining FITS over the years may be downloaded via this site. FITS-IDI files must conform to the 3.0 standard.

The theory of interferometry is described in Thompson, Moran, and Swenson [5]. The definitions of interferometric quantities that are used in this text correspond to those assumed in the present document except where explicitly noted.

To use this document, begin by reading the preface and introduction. The preface introduces the notation used in this document while the introduction provides an overview of the contents of a FITS-IDI file and introduces the terminology and conventions used to describe these data. The remaining chapters contain reference materials and may be read in any order.

In the interests of keeping this document to a reasonable length, the reference chapters do not make any specific mention of any elements that can be inferred to be present from the requirements that FITS-IDI files be valid FITS files, as defined by version 3.0 of the standard, unless they have some additional meaning in the context of a FITS-IDI file (*e.g.*, NAXIS values in tables). Although they are omitted from this document, these elements should be taken to be mandatory in FITS-IDI files.

Character strings that should appear in FITS-IDI files exactly as they are written will be presented in a `typewriter-like` font. This font will also be used for the names of computer programs. Character-string values for FITS header keywords will be marked with single quotation marks, as in `'a character string'`; the quotation marks do not form a part of the string value but are required delimiters. Some keywords used in FITS files consist of a fixed portion followed by an integer suffix that may be different in different context. These will be indicated like `NAXIS`*n*, where the *n* denotes the integer suffix. Parameters that may have different values under different circumstances are denoted in *italic font*.

The use of the word "shall" in this document should be interpreted as indicating a requirement on a FITS-IDI file. The use of the words "shall not" should be interpreted as indicating a prohibition.

Each keyword in a FITS header is associated with a value that has a specific type. In this document, these types are denoted by the letters shown in Table 1.

TABLE 1: Type codes for keyword values

Code	Type
I	integer number
L	logical
A	character string
E	floating-point number
D	date string

A date is a character string in one of two specific formats. The first format is `'`*DD*`/`*MM*`/`*YY*`'`, where *DD* is a two-digit day number, *MM* is a two-digit month number, and *YY* is a two-digit year number, suitable for use during the twentieth century. The preferred format is `'`*YYYY*`-`*MM*`-`*DD*`'`, where *YYYY* is a four-digit year number suitable for use in any recent century. Although the FITS standard allows times to be appended to the second form of a date string, times should not be appended to date strings in FITS-IDI files.

Each column in a FITS binary table has a type which denotes the kind of values that may appear in that column. Each column holds a one-dimensional array of some base type with a fixed number of elements. The base type of an array is denoted by a single-character code in this document. These codes correspond to those used for the `TFORM`*n* values in the table header and are listed in Table 2.

TABLE 2: Basic types for fields in binary tables

Code	Type
L	logical
I	16-bit integer
J	32-bit integer
A	character
E	32-bit floating-point number
D	64-bit floating-point number

In the simplest case, the number of elements in the array is given as a repeat count preceding the code for the basic type, *e.g.*, `4J` for an array of four 32-bit integers. Some fields are, however, considered to be multi-dimensional arrays in FITS-IDI tables despite being declared as one-dimensional arrays in the FITS headers. In these cases, the array dimensions will appear in parentheses following the basic type, *e.g.*, `E(4, 32)` for a two-dimensional array with 4 columns and 32 rows. In the table header, the repeat count shall be the product of all the dimensions and the data in the array shall be laid out so that the index of the first dimension varies fastest, followed by the second dimension, and so on. *The FITS-IDI Convention does not use the multi-dimensional array convention of the FITS standard and programs that read FITS-IDI files should not rely on the presence of* `TDIM`*n keywords.* This document occasionally uses a parenthesized dimension for one-dimensional arrays instead of a repeat-count prefix.

Character strings are a special case in that a one-dimensional array of characters should be taken to be a single string rather than an array of separate characters. Repeat-count prefixes will always be used to describe columns that contain character strings.

A number of arrays have dimensions that depend on the parameters of the data set or of the table to which they belong. The notations used for these parameters are listed in Table 3.

TABLE 3: Data set parameters

Notation	Parameter
n_{stokes}	Number of Stokes parameters in the data set
n_{band}	Number of bands in the data set
n_{chan}	Number of spectral channels in the data set
n_{tone}	Maximum number of pulse-cal tones in `PHASE-CAL` table
n_{orb}	Number of orbital parameters in an `ARRAY_GEOMETRY` table
n_{poly}	Number of terms in a delay polynomial in an `INTERFEROMETER_MODEL` table
n_{tab}	Maximum number of tabulated values or terms for a gain curve in a `GAIN_CURVE` table

2 Introduction

A FITS-IDI file contains raw visibility data and the information that is required in order to be able to interpret those data. It may also contain information that may be used to calibrate the raw data. Astronomical institutions may use the FITS-IDI format to exchange data with other institutions or to archive data.

The information contained in a FITS-IDI file is carried in a set of FITS binary tables. This makes the FITS-IDI Convention more resilient to media errors than the random-groups FITS format that is commonly used to transport radio interferometry data. The effects of a single media error are confined to the table in which it occurs in a FITS-IDI file while a single media error may render an entire random-groups file unusable. Programs that write FITS-IDI files may break the data into many small tables in multiple physical files to minimize the risk to the data. Furthermore, the use of the random-groups form has been "deprecated" by the international FITS community; readers for table-format files are widespread in the community, whilst random-groups readers are quite restricted in occurrence.

2.1 Visibility data

The main content of a FITS-IDI file is visibility data. This is stored on one or more `UV_DATA` tables.

Measurements of the visibility function depend on several parameters including the antennæ from which the signals are correlated, the polarizations of the feeds that were used at each antenna, the coordinates of the interferometer baseline, the sky frequency to which the measurement corresponds, and so forth.

Some of these parameters may be mapped onto a regular grid. These parameters are termed *regular parameters*. Visibility measurements are arranged in a multi-dimensional *data matrix* in which each axis corresponds to a regular parameter. Grid cells are numbered along each axis starting with one. The general form of the mapping between cells in the data matrix and the regular parameters is established for each axis by specifying a *reference value* for the parameter c_{ref}, the grid coordinate or *reference pixel* coordinate to which this value applies p_{ref} (not necessarily an integer) and the increment in the parameter value between grid cells Δc. The parameter value corresponding to a cell at location i on the axis in question is then given by Eq. 1.

$$c = c_{ref} + (i - p_{ref}) \cdot \Delta c\,. \tag{1}$$

Frequency coordinates are a special case and will be dealt with below; see Section 2.3 on page 7.

Those parameters that are not mapped to axes of the data matrix are termed *random parameters*. Visibility data in a FITS-IDI file are stored as a set of data matrices, each of which is labeled by a set of random parameter values. Every data matrix has the same dimensions and is labeled using the same list of random parameters.

Each visibility measurement is recorded as a complex number and is assigned a real weight. There are three possible weighting conventions:

1. The weight may be assigned a number between 0.0 and 1.0 and represents the fraction of the integration

time for which valid data were accumulated. In this case it is assumed that the visibility data in the FITS-IDI file should be normalized by dividing by the weight whenever the weight is not zero.

2. The weight may be a data validity flag which either has the value 0.0 if the measurement is not valid or the value 1.0 if the measurement is valid.

3. The weight may be any number representing the uncertainty in the units used for the visibilities to the -2 power. These weights are not used to scale the visibility data. Weights less than or equal 0.0 indicate that the data are invalid. These weights are then similar to the weights used in many software packages. The use of this type of weight shall be indicated by a table keyword.

Note that the second case can be regarded as a special case of the first in which data are either accumulated for the whole integration period or not at all.

A visibility measurement is assumed to be formed from the product of the output of the first antenna of a baseline pair and the complex conjugate of the output from the second antenna of the pair while baseline coordinates are assumed to be the coordinates of the first antenna of the pair with respect to the second antenna of the pair. Both conventions are consistent with those used in Thompson, Moran, & Swenson (2001) [5] and the NRAO Summer School lectures on synthesis imaging [4]. However, this phase convention is the opposite of that used internally, and in the FITS files written by, the AIPS software package, although the baseline convention is the same.

2.2 Arrays

The antennæ used for observations in a FITS-IDI file are grouped into *arrays*. There must be at least one array in the file and each array is assigned a positive number. The array numbers must be contiguous and must start with one.

A single antenna may belong to more than one array, but cannot be observing as part of more than one array at any given time. Antenna pairs ("interferometers") may only be formed between antennæ that are observing as members of the same array.

Each array has a corresponding `ARRAY_GEOMETRY` table in the FITS-IDI file. This table contains information about the time system used by the array and the coordinates of the antennæ that form the array. It also specifies an *array reference frequency*. Frequencies for observations taken using this array are given relative to this frequency.

2.3 Frequency setups

In general, a correlator produces visibility measurements at a fixed number of evenly spaced frequency channels. Each such grouping of frequencies is termed a *band*. A single interferometer can produce data for several bands simultaneously. The FITS-IDI Convention assumes that each interferometer used in the observations produces the same number of bands and labels them by number from 1 to n_{band} so that the band number may be mapped onto one axis of the data matrix. Each band is assumed to have an identical number of channels n_{chan} and the channels are mapped to another axis of the data matrix.

Each band b is characterized by a frequency offset $\nu_{off}(b)$, a channel bandwidth $\Delta\nu(b)$ which is always positive, and a sideband. The frequency at the *center* of channel c in band b is given by Eq. 2 for an upper sideband and Eq. 3 for a lower sideband, where ν_a is the array reference frequency, $\nu_s(b)$ is the source-specific frequency offset for band b, and p_{ref} is the reference pixel for the frequency axis.

$$\nu(c,b) = \nu_a + \nu_s(b) + \nu_{off}(b) + (c - p_{ref}) \cdot \Delta\nu(b) \tag{2}$$
$$\nu(c,b) = \nu_a + \nu_s(b) + \nu_{off}(b) + (1 + n_{chan} - p_{ref} - c) \cdot \Delta\nu(b)\,. \tag{3}$$

The characteristic settings for a band may be changed during the course of the observations. A complete set of frequency offsets, channel bandwidths, and sideband settings for every band is termed a *frequency setup*.

The frequency setups used in the file are listed in the `FREQUENCY` table and each setup is assigned a unique positive number. This number is one of the random parameters of the data matrix.

The `FREQUENCY` table may be omitted from a FITS-IDI file if and only if

- there is only one band in the file,
- that band is an upper sideband, and
- the channel bandwidth is constant throughout the observations.

In this case, the frequencies for each channel are calculated using Eq. 1, with the necessary frequency information conveyed using standard FITS header keywords.

2.4 Sources

Each position on the sky that has been observed is termed a *source*, regardless of whether there is an actual radio source at that location. Information about the sources for which data exists in the FITS-IDI file is recorded in a `SOURCE` table. Each source is assigned a unique positive *source identification number*. This number is one of the random parameters of the data matrix.

The `SOURCE` table can be omitted if and only if the file contains observations of a single source. Source information should still be provided, but standard FITS header keywords suffice.

2.5 Feed polarization

Each feed on an antenna is nominally sensitive to a single hand of polarization and is given a label that indicates the polarization to which it is nominally sensitive. These labels are listed in Table 4. The horizontal axis of an alt-azimuth antenna is taken to be perpendicular to the line of sight and parallel to the horizon when the antenna is observing a source at the horizon while the vertical axis is taken to be perpendicular to the horizon. The horizontal axis of an equatorial antenna is taken to be perpendicular to the line of sight and parallel to the celestial equator when the antenna is observing a source on the equator while the vertical axis is perpendicular to the equator. A feed is said to be sensitive to horizontal linear polarization if it is primarily sensitive to radiation with an electric vector parallel to the horizontal axis of the antenna. Note that the X and Y notation for linear polarization has caused much confusion with some calling X horizontal and some calling it vertical. We have replaced that nomenclature here in agreement with Thompson, Moran, and Swenson. As an example of the confusion, the previous version of this document declared X to be horizontal but with the orientation and ellipticity of verstical.

TABLE 4: Feed polarization labels

Label	Nominal sensitivity
R	Right circular (IAU convention)
L	Left circular (IAU convention)
V	Vertical linear
H	Horizontal linear

Real feeds are not purely sensitive to one polarization, but are also partially sensitive to the orthogonal polarization. This may be characterized in two ways.

The simplest is a linear approximation in which the output of a feed that is nominally sensitive to polarization i has the form shown in Eq. 4 where E_i is the incident electric field with polarization i, E_j is the incident electric field with orthogonal polarization, and D_{ij} is a complex constant that is called a *leakage term* and for which $|D_{ij}| \ll 1$.

$$V_i \propto E_i + D_{ij} \cdot E_j \tag{4}$$

A more general parameterization is in terms of the orientation and ellipticity of the feed. The orientation of the feed is the angle of the major axis of the ellipse generated by the electric field to which the feed is sensitive, measured from the vertical axis as defined above and increasing counter-clockwise as viewed along the line of sight. The ellipticity of the feed is the arctangent of the ratio of the minor axis of this ellipse to its major axis and is positive if the feed is sensitive to right circular polarization. The orientations and ellipticities of ideal feeds are summarized in Table 5:

TABLE 5: orientation/ellipticity parameters for ideal feeds

polarization	orientation	Ellipticity
R	0°	45°
L	0°	−45°
V	0°	0°
H	90°	0°

Information about the leakage terms associated with a feed or about the orientation and ellipticity of a feed may be carried in an `ANTENNA` table.

2.6 Stokes parameters

Each visibility observation measures a combination of two polarizations, one from each component of the interferometer. There are four possible combinations for circular polarizations that are labeled RR, LL, RL, and LR and four possible combinations for linear polarizations that are labeled VV, HH, VH, HV[1]; in each case the first letter labels the polarization of the first input and the second that of the second input.

In either case, the simple polarizations may be combined to obtain visibility measurements for the Stokes parameters I, Q, U, and V (IAU definitions are used). FITS-IDI follows *AIPS* terminology by using the term "Stokes parameters" to refer to both the true Stokes parameters and the simple polarization combinations. Each Stokes parameter is assigned a numeric code as shown in Table 6 so that the Stokes parameter may form a regular axis of the data matrix. While theoretically possible, it is recommended to avoid combining unlike polarizations (those from different groups in Table 6) on one regular axis.

TABLE 6: Numeric codes for Stokes parameters

Code	Parameter
1	I
2	Q
3	U
4	V
−1	RR
−2	LL
−3	RL
−4	LR
−5	VV
−6	HH
−7	VH
−8	HV

[1] previously called XX, YY, XY, and YX

2.7 Calibration and flagging information

A FITS-IDI file may also contain optional information that may be used to calibrate and edit the data.

`FLAG` tables list data that are known or suspected to be bad and that should be removed from the data set before further processing.

`SYSTEM_TEMPERATURE` tables list system and antenna temperatures for some or all of the antennæ that were used during the observations. If the system temperature T_s and antenna temperature T_a are known for both antennæ i and j used as an interferometer pair, then the true visibility $\Gamma(i,j)$ is related to the correlation coefficient measured by the interferometer $\gamma(i,j)$ by Eq. 5, where S is the flux density of the source being observed.

$$\Gamma(i,j) = \sqrt{\frac{T_s(i)}{T_a(i)}}\sqrt{\frac{T_s(j)}{T_a(j)}} \cdot S \cdot \gamma(i,j) \tag{5}$$

If the antenna temperatures are not known then the antenna gains $G(i)$ and $G(j)$ may be used as in Eq. 6. Antenna gains are carried in a `GAIN_CURVE` table either as tabulated values or as parameterized functions.

$$\Gamma(i,j) = \sqrt{\frac{T_s(i)}{G(i)}}\sqrt{\frac{T_s(j)}{G(j)}} \cdot \gamma(i,j) \tag{6}$$

The hybrid case may also be used if antenna temperatures are available for one antenna of the pair and an antenna gain for the other.

FITS-IDI files may also carry phase calibration data. The phases of signals injected at discrete frequencies at some defined point in the receiver path may be measured by the correlator and are recorded in `PHASE-CAL` tables. These measurements may be used to correct bandpass phases for frequency-dependent phase offsets that have been introduced in the receiving system.

In addition, a FITS-IDI file may carry spectral-channel dependent complex gains tabulated in a `BANDPASS` table. These amplitude and phase corrections depend on both band and spectral channel and are applied to the visibility data in addition to any corrections implied by the previously mentioned tables. Other, more recently defined tables are `BASELINE` for baseline-specific gain factors, `CALIBRATION` for complex gains as a function of time, and `WEATHER` for meteorological data.

3 FITS-IDI file structure

As pointed out in the introduction, all of the data in a FITS-IDI file are carried in the form of binary tables. The primary header-data-unit (HDU) contains no data.

3.1 The primary HDU

The primary HDU serves three purposes:

1. It indicates that the file contains FITS-IDI data.
2. It carries general information that applies to all of the FITS-IDI data in the file.
3. It carries a record of the processing performed on the data up to the point that the file was written.

In addition to the keywords mandated by the FITS standard, the primary header of a FITS-IDI file shall contain the keywords listed in Table 7 with the values shown in that table. This combination of keywords and values is the signature of a FITS-IDI file. Note that this is a header for a random-groups FITS data set that contains no data.

TABLE 7: Mandatory keywords for the primary header in the FITS-IDI convention

Keyword	Value type	Value
BITPIX	I	8
NAXIS	I	0
EXTEND	L	T
GROUPS	L	T
GCOUNT	I	0
PCOUNT	I	0

The keywords shown in Table 8 are used to record information about the correlator used to produce the present visibility data. The first keyword records the name/type of the correlator and has default value `'VLBA'`. The only values of `CORRELAT` which cause any special action in `FITLD` at this time are `'VLBA'` (explicitly or by default) and `'DIFX'`, which differentiates the DiFX VLBA software correlator from the VLBA hardware correlator. The second keyword records the version number of the software that generated a FITS-IDI file. It triggers special processing in *AIPS* program `FITLD`, when `CORRELAT` indicates the VLBA correlator, to deal with VLBA data that can include multiple integration times. It should be used in FITS-IDI files from other sources only if the `CORRELAT` keyword is also used with value other than blank or `'VLBA'`.

TABLE 8: Header keywords reserved for FITS-IDI

Keyword	Value type	Value
CORRELAT	A	Name/type of correlator
FXCORVER	A	Version number of the correlator software that produced the file

Information about the processing up to the point where the FITS file was created should be recorded in `HISTORY` records in the primary header.

3.2 Binary tables

The first FITS extension in the file shall follow immediately after the primary HDU.

The FITS-IDI data are carried in binary tables which can be identified by the value of their `EXTNAME` keyword. If a table has an `EXTNAME` keyword value that is listed in Table 9, then it shall have the structure described in the corresponding chapter of this document.

TABLE 9: FITS-IDI binary tables

EXTNAME value	Contents	Page
ANTENNA	Antenna polarization information	20
ARRAY_GEOMETRY	Time system information and antenna coordinates	17
BANDPASS	Channel-dependent complex gains	37
BASELINE	Baseline-specific gain factors	36
CALIBRATION	Complex gains as a function of time	39
FLAG	Information for flagging data	33
FREQUENCY	Frequency setups	22
GAIN_CURVE	Antenna gain curves	28
INTERFEROMETER_MODEL	Correlator model parameters	25
PHASE-CAL	Phase cal measurements	31
SOURCE	Information on sources observed	23
SYSTEM_TEMPERATURE	System and antenna temperatures	27
UV_DATA	Visibility data	12
WEATHER	Meteorological data	34

Other FITS extensions may be freely interleaved with these binary tables, but must not use the extension names listed in Table 9 nor those reserved for the VLBA in Table 10.

It is recommended that the ARRAY_GEOMETRY, SOURCE, and FREQUENCY tables be written in any order immediately following the primary HDU. These should be followed by all of the other table types in any order, except for the UV_DATA tables which should be last. This ordering allows FITS-IDI tables to be interpreted in a single pass through the file. It also places the large UV_DATA tables last after all of the tables which must be successfully read in order to render the visibility data interpretable.

TABLE 10: Extension names reserved for use by the VLBA

EXTNAME value	Contents	Page
CALC	Inputs to the CALC program	
MODEL_COMPS	Models generated by CALC	41
GATEDUTY	Pulsar gating information	
GATEMODL	Model used for pulsar gating	
SPACECRAFT_ORBIT	Spacecraft coordinates	
TAPE_STATISTICS	Tape statistics	
VLBA_EPHEMERIS	Ephemeris data	
VLBA_SAMPLER	Sampler settings	

All of the tables that are part of the FITS-IDI data set shall contain the keywords listed in Table 11. The values for OBSCODE, NO_STKD, STK_1, NO_BAND, NO_CHAN, REF_FREQ, CHAN_BW, and REF_PIXL must be the same in each table. In future revisions of the FITS-IDI Convention, it may be possible for a single file to contain several data sets, in which case these keywords will be used to identify the data set to which a table belongs. The current version of the FITS-IDI Convention only allows one data set per file, but these keywords are still needed to establish the overall characteristics of the data.

TABLE 11: Mandatory keywords for FITS-IDI tables

Keyword	Value type	Value
EXTNAME	A	Table name
TABREV	I	Revision number of the table definition
OBSCODE	A	Observation identification
NO_STKD	I	The number of Stokes parameters
STK_1	I	The first Stokes parameter coordinate value
NO_BAND	I	The number of bands
NO_CHAN	I	The number of spectral channels per band
REF_FREQ	E	The file reference frequency in Hz
CHAN_BW	E	The channel bandwidth in Hz for the first band in the frequency setup with frequency ID number 1
REF_PIXL	E	The reference pixel for the frequency axis

These keywords will not be repeated in the descriptions of the individual tables in subsequent Sections, other than the UV_DATA Section immediately following. A complete example of all primary and table headers is shown in the Appendix beginning on 44.

4 The UV_DATA table

A UV_DATA table contains a set of visibility matrices. If there is more than one UV_DATA table in the file, then no two tables shall contain data for overlapping times and the times shall occur in time order in the file.[2]

[2]These restrictions may be lifted in future revisions of the FITS-IDI Convention.

4.1 The data matrix and random parameters

Each row in the table contains a single data matrix that is stored in a designated column of the table.[3] The remaining columns correspond to the random parameters. The column containing the data matrix shall be indicated by setting the string-valued keyword `TTYPE`*n* to `'FLUX'` and the logical-valued keyword `TMATX`*n* to `T`, where *n* is the number of the column containing the data matrix. The `TUNIT`*n* keyword shall have the value `'JY'` or `'UNCALIB'`. An `NMATRIX` keyword shall be present with the value 1 to indicate that there is one data matrix for each row.

The number of axes for the data matrix shall be given as the value of the `MAXIS` keyword. Each axis *m* shall have a corresponding `MAXIS`*m* keyword that gives the number of pixels along the axis, a `CTYPE`*m* keyword that gives the name of the axis, a `CDELT`*m* keyword that gives the parameter increment along the axis, a `CRVAL`*m* keyword that gives the reference value for the axis, and a `CRPIX`*m* keyword that gives the reference pixel coordinate for the axis.

The column containing the data matrix shall be a single-precision floating-point column and each entry in the column shall have a number of elements equal to the product of the values of the `MAXIS`*m* keywords.

4.1.1 Regular axes

The axis names listed in Table 12 are recognized in the current version of the FITS-IDI Convention. Most of these are required to be present.

TABLE 12: Regular axes for the data matrix

Name	Mandatory ?	Description
`COMPLEX`	yes	Real, imaginary, weight
`STOKES`	yes	Stokes parameter
`FREQ`	yes	Frequency (spectral channel)
`BAND`	no	Band number
`RA`	yes	Right ascension of the phase center
`DEC`	yes	Declination of the phase center

The `COMPLEX` axis shall be the first (*i.e.*, the fastest changing) axis in the data matrix. It shall have a `MAXIS1` value of 2 or 3 and `CDELT1`, `CRPIX1`, and `CRVAL1` shall all have the value 1.0. The first entry on this axis contains the real part of a complex visibility and the second contains the corresponding imaginary component. If a third element is present, then this shall contain the weight for this visibility measurement. See Section 2.1 on page 6.

The `STOKES` axis enumerates polarization combinations. The corresponding `MAXIS`*m* value shall be no less than 1 and no greater than 4. The `CRPIX`*m* value shall be 1.0. See Section 2.6 on page 9. The value of the `MAXIS`*m* shall match that of the `NO_STKD` keyword and the value of the `CRVAL`*m* shall match that of the `STK_1` keyword. See Table 11 on page 12.

The `FREQ` axis enumerates frequency channels. The corresponding `CRVAL`*m* shall have the reference frequency for array number 1 as its value. Both `CRVAL`*m* and `CDELT`*m* are given in Hz. See Section 2.3 on page 7. The value of the `MAXIS`*m* keyword shall be identical to that of the `NO_CHAN` keyword, the value of the `CRVAL`*m* shall be identical to that of the `REF_FREQ` keyword, the value of the `CRPIX`*m* keyword shall be identical to the `REF_PIXL` keyword, and the value of the `CDELT`*m* keyword shall be identical to that of the `CHAN_BW` keyword. See Table 11 on page 12.

The `BAND` axis enumerates frequency bands. The corresponding `CRVAL`*m*, `CRPIX`*m*, and `CDELT`*m* keywords shall all have the value 1.0. See Section 2.3 on page 7. The `MAXIS`*m* keyword shall have the same value as

[3] The previous FITS-IDI documents contain the statement that "the structure of the `UV_DATA` table follows the conventions established in the draft document *A FITS Binary Table Convention for Interchange of Single-Dish Data in Radio Astronomy* by Harvey S. Liszt." There is no evidence that this is true and so it has been omitted here.

the NO_BAND keyword. See Table 11 on page 12. The BAND axis may be omitted if and only if there is only one band and there is only one frequency setup. In this case, the NO_BAND keyword shall have the value 1.

The RA and DEC axes shall both have the corresponding MAXISm values of 1. If only one source is present in the file and no SOURCE tables are present, then the CRVALm keyword for the RA axis shall give the right ascension of the phase center in degrees and the CRVALm keyword for the DEC axis shall give the declination of the phase center in degrees. These coordinates shall be those of the standard equinox and that standard equinox shall be specified in the table header. If more than one source is present in the file, then the CRVALm keywords for both the RA and the DEC axes shall have the value 0.0 and no equinox need be specified.

4.1.2 Random parameters

The name of each random parameter is given as the value of the corresponding TTYPEn keyword, where n is the column number in which the value of the random parameter appears. The recognized values are listed in Table 13.

TABLE 13: Random parameter names

Name	Type	Units	Description
UU	1D or 1E	seconds	u baseline coordinate (-SIN system)
VV	1D or 1E	seconds	v baseline coordinate (-SIN system)
WW	1D or 1E	seconds	w baseline coordinate (-SIN system)
UU---SIN	1D or 1E	seconds	u baseline coordinate (-SIN system)
VV---SIN	1D or 1E	seconds	v baseline coordinate (-SIN system)
WW---SIN	1D or 1E	seconds	w baseline coordinate (-SIN system)
UU---NCP	1D or 1E	seconds	u baseline coordinate (-NCP system)
VV---NCP	1D or 1E	seconds	v baseline coordinate (-NCP system)
WW---NCP	1D or 1E	seconds	w baseline coordinate (-NCP system)
DATE	1D	days	Julian date at 0 hours
TIME	1D	days	Time elapsed since 0 hours
BASELINE	1J		Baseline number
ARRAY	1J or 1I		Array number
SOURCE_ID	1J or 1I		Source ID number
FREQID	1J or 1I		Frequency setup ID number
INTTIM	1D or 1E	seconds	Integration time
WEIGHT	E(n_{stokes},n_{band})		Weights
GATEID	1J		VLBA specific
FILTER	1J		VLBA specific

Baseline coordinates. Three of the random parameters shall be used to specify the baseline coordinates for the visibility measurements in light seconds. The three coordinates are designated by names that begin with UU, VV, and WW, which correspond to the $u, v,$ and w coordinates at the coordinate equinox. The first two letters may be followed by an optional suffix that indicates the coordinate system used for the baseline coordinates. If the suffix is omitted, then the ---SIN convention is assumed. The suffixes must match on all three baseline coordinate parameters.

If the suffix is ---SIN, then the w axis lies along the line of sight to the source and the u and v axes lie in a plane perpendicular to the line of sight with v increasing to the north and u increasing to the east. If the suffix is ---NCP, then the w axis points to the north pole, the v axis is parallel to the projection of the line of sight into the equator with the v coordinate increasing away from the source and the u coordinate completes the right-handed Cartesian triad (u, v, w). Note that the ---NCP system is normally used only with East-West interferometers in which the value of w is zero.

Important note: There have been several errors in the choice of suffixes. Flatters 1998 [2] erroneously specified suffixes with only two minus signs, --SIN and --NCP. The VLBA archive erroneously uses the suffix `-L`, which normally means units of wavelengths but not when used by the VLBA archive. Therefore, FITS-IDI readers should recognize these three suffixes as `---SIN`, `---NCP`, and `---SIN`, respectively, with units of seconds.

DATE and TIME. Two random parameters shall be used to record the time at which the visibility measurements in a record were taken. The value of the `DATE` parameter shall be the Julian date at midnight on the day the measurement was made using the appropriate time system for the array used for the measurement. The `TIME` parameter shall be the number of days that have elapsed since midnight. The time recorded using `DATE` and `TIME` shall be the central time in the integration period and shall also be the time at which the (u, v, w) coordinates are valid.

Integration time. The length of the period over which the data were integrated may optionally be supplied in seconds as the value of the `INTTIM` parameter.

Baseline specification. The baseline (telescope pair) from which the data were obtained shall be specified using two parameters. The `ARRAY` parameter shall give the number of the array that was used for the observations and the `BASELINE` parameter shall give the antenna numbers of the two antennæ of the antenna pair within this array. The baseline number is formed by multiplying the number of the first antenna by 256 and then adding the number of the second antenna. The `ARRAY` parameter may be omitted if and only if there is only one array defined in the file.

Source identification number. If the file contains observations of more than one source, then the identification number of the source being observed shall be given as the value of the `SOURCE_ID` parameter. Note that this random parameter name has also been spelled with a blank instead of the underscore and omitting the `'_ID'` entirely. All three spellings should be regarded as synonymous.

Frequency setup number. If the file contains observations made using more than one frequency setup, then the identification of the frequency setup that was used shall be recorded as the value of the `FREQID` parameter.

Weights. If the weights assigned to all spectral channels in a band are identical, the weights may be recorded in a `WEIGHT` random parameter. The value of this parameter shall be an array that is indexed by band number and by pixel coordinates on the `STOKES` axis. Each element in this array is the weight that should be given to all data points for that band and polarization. If `MAXIS1` has the value 2, then a `WEIGHT` parameter must be present. Conversely, if `MAXIS1` has the value 3, then a `WEIGHT` parameter must not be present.

4.2 Table header keywords

TABLE 14: Mandatory keywords for UV_DATA headers

Keyword	Value type	Value
EXTNAME	A	'UV_DATA'
TABREV	I	2
NMATRIX	I	1
MAXIS	I	M = number axes in regular matrix
MAXISm	I	Number pixels on axis $m = 1$ to M
CTYPEm	A	Name of regular axis $m = 1$ to M
CDELTm	E	Coordinate increment on axis $m = 1$ to M
CRPIXm	E	Reference pixel on axis $m = 1$ to M
CRVALm	E	Coordinate value at reference pixel on axis $m = 1$ to M
TMATXn	L	T — column n contains the visibility matrix
NO_STKD	I	The number of Stokes parameters
STK_1	I	The first Stokes parameter coordinate value
NO_BAND	I	The number of bands
NO_CHAN	I	The number of spectral channels per band
REF_FREQ	E	The file reference frequency in Hz
CHAN_BW	E	The channel bandwidth in Hz for the first band in the frequency setup with frequency ID number 1
REF_PIXL	E	The reference pixel for the frequency axis
EQUINOX	8A	Mean equinox
WEIGHTYP	8A	Type of data weights

The keywords and values shown in Table 14 must appear in the header of each UV_DATA table. Keywords from EXTNAME through REF_PIXL are mandatory in all headers, whilst the keywords EQUINOX and WEIGHTYP are mandatory only in special cases. See the discussion of "Regular axes" beginning on page 13 for a description of keywords MAXIS though TMATXm. A set of MAXISm through CRVALm must appear for each of the M axes, where M is the value of the keyword MAXIS. The mandatory, common keywords of Table 11 discussed on page 12 are repeated here, but will not be repeated in the descriptions of the other tables. The standard FITS keywords required to characterize a binary table fully are also required in the headers of all FITS-IDI tables.

EQUINOX shall be equal to a string identifying the standard mean equinox used for the source coordinates when data for only one source appears in the UV_DATA table. This shall be either '1950.0B' or 'J2000'.

WEIGHTYP shall be equal to a string identifying the type of weights accompanying the visibility data. Value 'NORMAL' means that the weights represent true weights (one over uncertainty squared). Value 'CORRELAT' means that the weights are between 0 and 1 and should be divided into the accompanying visibilities. Value 'CORRTIME' means that the visibilities must be divided by both the weight and the integration time in order to be brought onto a consistant scale. This keyword must appear unless 'CORRELAT' is desired. Note that the VLBA and EVN currently do not write this keyword, but use 'CORRTIME' and 'NORMAL' respectively.

TABLE 14b: Optional keywords for UV_DATA headers

Keyword	Value type	Value
DATE-OBS	D	Observing date
TELESCOP	A	Telescope name
OBSERVER	A	Observer's name
VIS_SCAL	E	Visibility scale factor
SORT	A	Sort order

The keywords and values shown in Table 14b may appear in the header of each UV_DATA table.

DATE-OBS shall give the date on which the observations were begun.

TELESCOP shall be a short string that is used to identify the instrument used to make the observations. This will normally identify the correlator.

OBSERVER will be a short string that is used to identify the observer or the project to which the data belong.

VIS_SCAL is a normalization factor which should be used to divide the amplitudes of all of the visibility data. This may be used to reduce the computational load on near-real time systems: such systems may write accumulated sums in the data matrix and store the normalization factor as the value of this keyword. If this keyword does not appear, its value will be taken to be 1.0. If WEIGHTYP = 'NORMAL', any VIS_SCAL will also be used to multiply, in its square, the weights as well as dividing into the visibilities.

SORT is a string of two characters that indicate, if not blank, that the data in the UV_DATA table are sorted. The first letter gives the primary sort key and the second letter the secondary sort key. In other words, the data are sorted in the order specified by the first letter and those records with identical values of this key are sorted according to the second letter. The characters are the first character of the random-parameter name of the parameter used for the sort key when sorted in ascending order. Special values include '*' and ' ' which mean no key, 'T' which means time including both DATE and TIME parameters, 'X' which means descending absolute value of UU, and 'Y' which means descending absolute value of VV.

5 The ARRAY_GEOMETRY table

The ARRAY_GEOMETRY tables define the arrays used in the file. Each ARRAY_GEOMETRY table lists the antennæ that are part of that array together with their coordinates. It also provides information about the time system used for that array. There must be an ARRAY_GEOMETRY table for each array used in the file.

5.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 15.

Array number. The array number for the array described by an ARRAY_GEOMETRY table shall be recorded as the value of the EXTVER keyword. Each ARRAY_GEOMETRY table in a FITS-IDI file must have a distinct value of EXTVER and there must be an ANTENNA table with an EXTVER value of one.

Array name. The value of the ARRNAM keyword shall be a name for the array that may be used in reports presented to human readers. Array names need not be unique and should not require more than 8 characters.

Coordinate frame. The value of the FRAME keyword shall be a string that identifies the coordinate system used for antenna coordinates. At present, only one value of the FRAME keyword has been defined; other coordinate definitions may be added in future revisions of the FITS-IDI Convention.

If the value of the FRAME keyword is 'GEOCENTRIC', the the coordinates are given in an Earth-centered, Earth-fixed, Cartesian reference frame. The origin of the coordinates is the Earth's center of mass. The z axis is parallel to the direction of the conventional origin for polar motion. The x axis is parallel to the direction of the intersection of the Greenwich meridian with the mean astronomical equator. The y axis completes the right-handed, orthogonal coordinate system. The coordinates are given in meters.

TABLE 15: Mandatory keywords for ARRAY_GEOMETRY table headers

Keyword	Value type	Value
EXTNAME	A	'ARRAY_GEOMETRY'
TABREV	I	1
EXTVER	I	Array number
ARRNAM	A	Array name
FRAME	A	Coordinate frame
ARRAYX	E	x coordinate of array center (m)
ARRAYY	E	y coordinate of array center (m)
ARRAYZ	E	z coordinate of array center (m)
NUMORB	I	n_{orb}= number orbital parameters in table
FREQ	E	Reference frequency (Hz)
TIMESYS	A	Time system
RDATE	D	Reference date
GSTIA0	E	GST at 0h on reference date (degrees)
DEGPDY	E	Earth's rotation rate (degrees/day)
UT1UTC	E	UT1 - UTC (sec)
IATUTC	E	IAT - UTC (sec)
POLARX	E	x coordinate of North Pole (arc seconds)
POLARY	E	y coordinate of North Pole (arc seconds)

Array center. The ARRAYX, ARRAYY, and ARRAYZ keywords shall give the coordinates of the array center in the coordinate frame specified by the FRAME keyword. Antenna coordinates in the main part of the table are given relative to the array center.

Orbital parameters. The value of the NUMORB keyword shall be the number of elements in the ORBPARM array in the main part of the table. This shall be either 0 or 6.

Reference frequency. The value of the FREQ keyword shall be the reference frequency in Hz for the array described in the present ARRAY_GEOMETRY table. See Section 2.3 on page 7. If the array number is one, then the value of the FREQ keyword shall be identical to that of the REF_FREQ keyword; see page 12.

Time system. The TIMSYS keyword shall specify the time system used for the array. It shall either have the value 'IAT', denoting international atomic time, or the value 'UTC', denoting coordinated universal time. This indicates whether the zero hour for the TIME parameter in the UV_DATA table is midnight IAT or midnight UTC.

Reference date. The value of the RDATE parameter will be the date for which the time system parameters GSTIA0, DECPDY, and IATUTC apply. If the table contains orbital parameters for orbiting antennæ, this keyword also designates the epoch for the orbital parameters.

GST at midnight. The value of the GSTIA0 keyword shall be the Greenwich sidereal time in degrees at zero hours on the reference date for the array in the time system specified by the TIMESYS keyword.

Earth rotation rate. The value of the DEGPDY keyword shall be the rotation rate of the Earth in degrees per day on the reference date for the array.

Difference between UT1 and UTC. The value of the UT1UTC keyword shall be the difference between UT1 and UTC in seconds on the reference date for the array.

Difference between IAT and UTC. The value of the IATUTC keyword shall be the difference between IAT and UTC in seconds on the reference date for the array. Note that this always has an integral value and is the number of accumulated leap seconds on that date.

Polar position. The values of the POLARX and POLARY keywords shall give the x and y offsets of the North Pole in arc seconds on the reference date for the array with respect to the coordinate system specified by the FRAME keyword. The units were changed from the meters specified by the earlier documents, but seldom used in actual implementations. Note that arc seconds and meters can be told apart, at least in recent decades.

If $\sqrt{P_x^2 + P_y^2} < 0.6$, the units are arc seconds.

5.2 Table structure

Each row in the table provides information about a single antenna. Each of the columns listed in Table 16 must be present. The order of the columns does not matter.

TABLE 16: Mandatory and optional columns for the ARRAY_GEOMETRY table

Title	Type	Units	Description
ANNAME	8A		Antenna name
STABXYZ	3D	meters	Antenna station coordinates (x, y, z)
DERXYZ	3E	meters/s	First-order derivatives of the station coordinates with respect to time
ORBPARM	D(n_{orb})		Orbital parameters
NOSTA	1I		Antenna number
MNTSTA	1J		Mount type
STAXOF	3E	meters	Axis offset
DIAMETER	1E	meters	Antenna diameter

Antenna name. The antenna name shall be a character string that may be used to identify the antenna for a human user.

Station coordinates. The STABXYZ array shall give the coordinate vector (element 1 is the x coordinate, element 2 is the y coordinate, and element 3 is the z coordinate) of the antenna relative to the array center defined in the header, provided that the antenna is not an orbiting antenna. The coordinate system used for the antenna coordinates is indicated by the FRAME keyword in the header. The DERXYZ array shall give the first-order derivative of the antenna coordinate vector with respect to time in meters per second, provided that the antenna is not an orbiting antenna.

Orbital parameters. If the antenna is an orbiting antenna and orbital information is available, the ORBPARM array will contain the orbital parameters for the antenna as shown in Table 17. The orbital elements shall be those for 0 hours on the reference date for the array in the time system used for the array. The reference frame for the orbital parameters shall be the same as that used for u, v, w coordinates in the UV_DATA table.

TABLE 17: Contents of the ORBPARM array

Index	Parameter	Units
1	Semi-major axis of orbit (a)	meters
2	Ellipticity of orbit (e)	
3	Inclination of the orbit to the celestial equator (i)	degrees
4	The right ascension of the ascending node (Ω)	degrees
5	The argument of the perigee (ω)	degrees
6	The mean anomaly (M)	degrees

The dimension of the ORBPARM array is given by the value of the NUMORB keyword (n_{orb}). If this value is zero, then the ORBPARM column contains no values. If n_{orb} is 6, then all 6 orbital parameters shall be set to NaN (not a number) for all antennæ for which MNTSTA is not 2.

Antenna number. The NOSTA column shall contain a positive integer value that uniquely defines the antenna within the array. If the same antenna appears in more than one array, it need not have the same station number in each array. This is the antenna identification number that is used in other FITS-IDI tables.

Mount type. The MNTSTA column shall contain an integer value that encode the mount type of the antenna. Codes 0 for alt-azimuth, 1 for equatorial, and 2 for orbiting are defined. Codes 3 for X-Y, 4 for right-handed Nasmyth, and 5 for left-handed Nasmyth are hereby also defined. Aperture arrays, which are steered electronically rather than mechanically, are assigned code 6.

Axis offset. The STAXOF column shall contain the array of axis offsets for the antenna in x, y, z order.

Antenna diameter. The optional DIAMETER column shall give the antenna physical diameter. This information may be used in calculations of sensitivity and shadowing. information.

6 The ANTENNA table

The ANTENNA table contains information about the antennæ used in a FITS-IDI file that may change with time or with frequency setup. These characteristics include the polarization properties of the feeds and the number of digitizer levels.

6.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 18. The POLTYPE keyword may be omitted if the value of the NOPCAL keyword is zero.

TABLE 18: Mandatory keywords for ANTENNA table headers

Keyword	Value type	Value
EXTNAME	A	'ANTENNA'
TABREV	I	1
NOPCAL	I	$n_{pcal} = 0$ or 2, number of polarization calibration constants
POLTYPE	A	The feed polarization parameterization

Number of polarization calibration constants. The ANTENNA table may carry information about the polarization characteristics of the feeds if this is known. If information about the polarization characteristics of the feeds is contained in the table, then the NOPCAL keyword shall have the value 2. If no information about the polarization characteristics is contained in the table, then the NOPCAL keyword shall have the value 0.

Polarization parameterization. If the table contains information about the polarization characteristics of the feeds, then the feed parameterization that is used shall be indicated by the value of the POLTYPE keyword, as given in Table 19.

TABLE 19: Values for the POLTYPE keyword

Value	Model
'APPROX'	Linear approximation for circular feeds
'X-Y LIN'	Linear approximation for linear feeds
'ORI-ELP'	Orientation and ellipticity

6.2 Table structure

Each row in the table gives the parameters for one antenna in one frequency setup over a designated period of time. Each of the columns listed in Table 20 shall be present. The order of the columns does not matter.

Time covered by the record. The value in the TIME column shall be the number of days that have elapsed between 0 hours on the reference date for the current array and the center of the time period covered by the current row. The value in the TIME_INTERVAL column shall be the number of days covered by the current row.

Antenna identification. The value in the ANNAME column shall be the name of the antenna to which the current row applies. This should be identical to the name given in the ARRAY_GEOMETRY table. The value in the ANTENNA_NO column shall be the antenna identification number and the value in the ARRAY column shall be the array number of the antenna to which the current row applies.

TABLE 20: Mandatory and optional columns for the ANTENNA table

Title	Type	Units	Description
TIME	1D	days	Central time of period covered by record
TIME_INTERVAL	1E	days	Duration of period covered by record
ANNAME	8A		Antenna name
ANTENNA_NO	1J		Antenna number
ARRAY	1J		Array number
FREQID	1J		Frequency setup number
NO_LEVELS	1J		Number of digitizer levels
POLTYA	1A		Feed A polarization label
POLAA	E(n_{band})	degrees	Feed A orientation
POLCALA	E(n_{pcal},n_{band})		Feed A polarization parameters
POLTYB	1A		Feed B polarization label
POLAB	E(n_{band})	degrees	Feed B orientation
POLCALB	E(n_{pcal},n_{band})		Feed B polarization parameters
BEAMFWHM	E(n_{band})	degrees / m	Antenna beam fwhm

Frequency setup number. The value in the FREQID column shall be the number of the frequency setup to which the current record applies.

Number of digitizer levels. The value in the NO_LEVELS column shall be the number of digitizer levels for the antenna. This shall be 2 for Mk II and Mk III terminals and may be either 2 or 4 for VLBA terminals (depending on observing mode).

Polarization types. The value in the POLTYA column shall be the feed polarization of feed A. This corresponds to polarization 1 in calibration tables. The value in the POLTYB column shall be the feed polarization of feed B (if any). See Section 2.5 on page 8. The two feeds may be either circularly or linearly polarized. Mixtures of linear and circular polarizations are forbidden. If two orthogonal polarizations are used, it is strongly recommended that feed A (POLTYA) be 'R' or 'X' and feed B (POLTYB) be 'L' or 'Y'.

Feed orientations. The value of the POLAA columns shall be an array, each element of which is the orientation of feed A in the corresponding band, given in degrees. Similarly, the POLAB column shall contain the feed orientations for feed B. See Section 2.5 on page 8.

Polarization parameters. If the value of the NOPCAL keyword is 2, then the POLCA and POLCB columns shall contain 2 polarization parameters for each band for feeds A and B, respectively. If the value of the POLTYPE keyword is 'APPROX' or 'X-Y LIN', then the first parameter shall be the real part of the leakage term and the second shall be the imaginary part of the leakage term. If the value of the POLTYPE keyword is 'OTI-ELP', then the first parameter shall be the orientation and the second shall be the ellipticity and both shall be given in radians. See Section 2.5 on page 8.

Antenna beam. The optional column BEAMFWHM shall contain the full-width at half maximum of the (single-dish) beam of the antenna. It shall be expressed in degrees per meter and shall be assumed to scale with actual observing wavelength within the corresponding band.

7 The FREQUENCY table

The FREQUENCY table provides information about the frequency setups used in a FITS-IDI file. There shall be no more than one FREQUENCY table in a FITS-IDI file. If the FREQID random parameter is used in the UV_DATA tables, then a FREQUENCY table is mandatory.

7.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 21.

TABLE 21: Mandatory keywords for FREQUENCY table headers

Keyword	Value type	Value
EXTNAME	A	'FREQUENCY'
TABREV	I	1

7.2 Table structure

Each row in the table provides information about a single frequency setup. Each of the columns listed in Table 22 must be present. The order of the columns does not matter.

TABLE 22: Mandatory columns for the FREQUENCY table

Title	Type	Units	Description
FREQID	1J		Frequency setup number
BANDFREQ	D(n_{band})	Hz	Frequency offsets
CH_WIDTH	E(n_{band})	Hz	Individual channel widths
TOTAL_BANDWIDTH	E(n_{band})	Hz	Total bandwidths of bands
SIDEBAND	J(n_{band})		Sideband flag

Frequency setup number. The FREQID column shall contain the frequency setup number for the frequency setup. This shall be a positive integer that uniquely identifies the frequency setup. One of the frequency setups shall be assigned the frequency setup number 1.

Band frequency offsets. The BANDFREQ column shall contain a one-dimensional array of band-specific frequency offsets. There shall be one element for each band in the file. The offset for the first band in the frequency setup with FREQID value 1 should be 0 Hz. Frequency offsets may be of either sign.

Bandwidths. The CH_WIDTH column shall contain a one-dimensional array of channel bandwidths. There shall be one element for each band in the file and each element is the frequency spacing between adjacent channels in the corresponding band for the current frequency setup. Each entry shall be positive. The channel bandwidth for the first band in the frequency setup with FREQID value 1 shall be identical to the value of the CHAN_BW keyword.

The TOTAL_BANDWIDTH column shall contain a one-dimensional array of total bandwidths for each band. There shall be one element for each band in the file. The total bandwidth for a band is normally obtained by multiplying the channel bandwidth by the number of channels.

Sidebands. The SIDEBAND column shall contain a one-dimensional array of sideband flags. There shall be one entry for each band in the file. Each flag shall have the value +1 if the corresponding band is an upper sideband in the current frequency setup and −1 if the corresponding band is a lower sideband in the current frequency setup. See Sect. 2.3 on page 7.

8 The SOURCE table

The SOURCE table contains information about the sources for which data are available in the FITS-IDI file. There shall be no more than one SOURCE table in a FITS-IDI file. If the SOURCE_ID random parameter is used in the UV_DATA tables, then a SOURCE table is mandatory.

8.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 23.

TABLE 23: Mandatory keywords for SOURCE table headers

Keyword	Value type	Value
EXTNAME	A	'SOURCE'
TABREV	I	1

8.2 Table structure

Each row in the table provides information for one source for each frequency setup in which it is observed. Each of the columns listed in Table 24 must be present. The order of the columns does not matter.

TABLE 24: Mandatory and optional columns for the SOURCE table

Title	Type	Units	Description
SOURCE_ID	1J		Source ID number
SOURCE	16A		Source name
QUAL	1J		Source name numeric qualifier
CALCODE	4A		Calibrator code
FREQID	1J		Frequency setup number
IFLUX	E(n_{band})	Jy	Stokes I flux density
QFLUX	E(n_{band})	Jy	Stokes Q flux density
UFLUX	E(n_{band})	Jy	Stokes U flux density
VFLUX	E(n_{band})	Jy	Stokes V flux density
ALPHA	E(n_{band})	Jy	Spectral index for each band
FREQOFF	E(n_{band})	Hz	Frequency offset for each band
RAEPO	1D	degrees	Right ascension at mean equinox
DECEPO	1D	degrees	Declination at mean equinox
EQUINOX	8A		Mean equinox
RAAPP	1D	degrees	Apparent right ascension
DECAPP	1D	degrees	Apparent declination
SYSVEL	D(n_{band})	meters/sec	Systemic velocity for each band
VELTYP	8A		Velocity type
VELDEF	8A		Velocity definition
RESTFREQ	D(n_{band})	Hz	Line rest frequency for each band
PMRA	1D	degrees/day	Proper motion in right ascension
PMDEC	1D	degrees/day	Proper motion in declination
PARALLAX	1E	arcseconds	Parallax of source
EPOCH	1D	years	Epoch of observation

Source ID number. The SOURCE_ID column shall contain the source identification number for the source. The source identification number is a positive integer that uniquely identifies the source. The keyword name

'ID_NO.' has been used as a synonym by the VLBA correlator.

Source name and qualifier. The SOURCE column shall contain the name of the source. The QUAL column shall contain a *source qualifier*. The source qualifier is a positive integer that is used in combination with the name of the source to identify it to a human user. For example, if several regions about a named radio source are observed, the same source name may be used for all of them and they may be distinguished by having different source qualifiers.

Calibrator code. The CALCODE column shall contain a *calibrator code*. A calibrator code is an instrument-specific code that encodes information about the suitability of the source for use as a calibrator.

Frequency ID. The FREQID column shall contain the frequency setup number to which the current row applies.

Flux density information. The IFLUX column shall contain an array of flux densities. There shall be one entry for every band in the file and each entry shall be the flux density of the source in Stokes parameter I at the reference frequency for that band in the current frequency setup. Similarly, the QFLUX, UFLUX, and VFLUX columns shall contain arrays of flux densities for Stokes parameters Q, U, and V, respectively, for every band in the file appropriate to those bands in the current frequency setup. If the flux density is unknown, then the value shall either be zero or NaN (not a number).

Spectral indices. The ALPHA column shall contain an array of spectral indices. There shall be one entry for every band in the file and each entry shall be the spectral index of the source for that band in the current frequency setup. The spectral index α is defined such that the flux density $S(\nu)$ as a function of frequency ν, is related to the flux density at the reference frequency $S(\nu_0)$ following Eq. 7.

$$S(\nu) = S(\nu_0) \cdot (\nu/\nu_0)^{\alpha} \,. \tag{7}$$

Source-specific frequency offsets. The FREQOFF column shall contain an array of frequency offsets. There shall be one entry for each band in the file and each entry shall contain the source-specific frequency offset for that band in the frequency setup specified by the value in the FREQID column. The column gives the offsets in the frequency of the reference pixel on the frequency axis and should be added to the BANDFREQ value from the FREQUENCY table. See Sect. 2.3 on page 7.

Velocity information. The SYSVEL column shall contain an array of velocities. There shall be one entry for each band in the file and every entry shall give the systemic velocity of the source at the reference frequency for that band in the current frequency setup.

The VELTYP column shall contain a string that specifies the frame of reference for the systemic velocities. This string shall be one of those listed in Table 25.

TABLE 25: Frames of reference for VELTYP

Value	Frame of reference
LSR	Local standard of rest
BARYCENT	Solar system barycenter
GEOCENTR	Center of mass of the Earth
TOPOCENT	Uncorrected

The VELDEF column shall contain a string indicating the convention used for systemic velocities. It shall be either 'RADIO' or 'OPTICAL'.

The RESTFREQ column shall contain an array of rest frequencies. There shall be one entry for each band in the file and each entry shall contain the nominal rest frequency for the line being observed in the corresponding band for this source using the current frequency setup. This line is the spectral line defining the velocity information provided. If a rest frequency is not available for a particular band, then the corresponding entry should be zero or NaN. No provision is made for specifying more than one spectral line per band.

Source positions. The RAEPO column shall contain the right ascension of the phase center associated with the source at the standard mean equinox. The DECEPO column shall contain the declination of the phase center at the standard mean equinox. The EQUINOX column shall contain a string identifying the standard mean equinox used for the current source. This shall be either '1950.0B' or 'J2000'. The VLBA writes an EPOCH column in double precision containing 1950.0 or 2000.0. This VLBA column must be understood as equinox values not epoch values.

The RAAPP column shall contain the best available approximation[4] of the right ascension of the phase center associated with the source at 0 hours on the reference date for array 1. The DECAPP column shall contain the best available approximation of the declination of the phase center associated with the source at 0 hours on the reference date for array 1.

The PMRA column should contain the proper motion of the source in right ascension. The PMDEC column should contain the proper motion of the source in declination. The PARALLAX column should contain the parallax of the source. If the proper motions and/or parallax are unknown, then the corresponding fields should be set to 0. The optional EPOCH column must be given if any of these fields are not zero and is the date to which the equinox and apparemt positions of the moving source apply.

9 The INTERFEROMETER_MODEL table

The INTERFEROMETER_MODEL table contains information about the interferometer models used by the correlator. INTERFEROMETER_MODEL tables are optional.

9.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 26.

TABLE 26: Mandatory keywords for INTERFEROMETER_MODEL table headers

Keyword	Value type	Value
EXTNAME	A	'INTERFEROMETER_MODEL'
TABREV	I	2
NPOLY	I	Number of polynomial terms n_{poly}
NO_POL	I	Number of polarizations

Number of polynomial terms. Delays and rates are given as polynomials with n_{poly} terms as specified by the value of the NPOLY keyword. This shall be a positive integer.

Number of polarizations. The INTERFEROMETER_MODEL may contain information for one or two orthogonal polarizations. The number of polarizations shall be given by the NO_POL keyword.

9.2 Table structure

Each row of the table shall give the model information applicable to one antenna over a range of time. Each of the columns listed in Table 27 above the horizontal line must be present. The columns for the second polarization, listed below the horizontal line, must appear but only if the value of the NO_POL keyword is two. Polarization 1 corresponds to feed A in the ANTENNA table and polarization 2 to feed B. The order of the columns does not matter.

[4]There are no enforceable standards for the quality of this approximation. For example, the VLBA merely repeats the coordinates for the standard mean equinox in these fields.

TABLE 27: Mandatory columns for the INTERFEROMETER_MODEL table

Title	Type	Units	Description
TIME	1D	days	Starting time of interval
TIME_INTERVAL	1E	days	Duration of interval
SOURCE_ID	1J		Source ID number
ANTENNA_NO	1J		Antenna number
ARRAY	1J		Array number
FREQID	1J		Frequency setup number
I.FAR.ROT	1E	rad m^{-2}	Ionospheric Faraday rotation
FREQ.VAR	E(n_{band})	Hz	Time variable frequency offsets
PDELAY_1	D(n_{poly},n_{band})	turns	Phase delay polynomials for polarization 1
GDELAY_1	D(n_{poly},n_{band})	seconds	Group delay polynomials for polarization 1
PRATE_1	D(n_{poly},n_{band})	Hz	Phase delay rate polynomials for polarization 1
GRATE_1	D(n_{poly},n_{band})	sec/sec	Group delay rate polynomials for polarization 1
DISP_1	1E	sec m^{-2}	Dispersive delay for polarization 1
DDISP_1	1E	sec m^{-2}/sec	Rate of change of dispersive delay for polarization 1
PDELAY_2	D(n_{poly},n_{band})	turns	Phase delay polynomials for polarization 2
GDELAY_2	D(n_{poly},n_{band})	seconds	Group delay polynomials for polarization 2
PRATE_2	D(n_{poly},n_{band})	Hz	Phase delay rate polynomials for polarization 2
GRATE_2	D(n_{poly},n_{band})	sec/sec	Group delay rate polynomials for polarization 2
DISP_2	1E	sec m^{-2}	Dispersive delay for polarization 2
DDISP_2	1E	sec m^{-2}/sec	Rate of change of dispersive delay for polarization 2

Time covered by the row. The TIME column shall contain the earliest time covered by the current row as the number of days that have elapsed since 0 hours on the reference date in the time system used for the array. This is also the zero time for the delay and rate polynomials. The TIME_INTERVAL column shall contain the number of days for which the model described by the row remains valid. Note that the INTERFEROMETER_MODEL table differs from the other FITS-IDI tables in that the value in the TIME column is the beginning of the interval covered and not the center of the interval.

Source identification number. The SOURCE_ID column shall contain the source identification number of the source for which the model is valid.

Antenna and array numbers. The ANTENNA_NO column shall contain the antenna identification number of the antenna to which the model applies. The ARRAY column shall contain the array number of the array to which the antenna belongs.

Frequency setup number. The FREQID column shall contain the frequency setup number of the frequency setup for which the model applies.

Ionospheric Faraday rotation. The I.FAR.ROT column shall contain the value of the ionospheric Faraday rotation applied at the correlator. If no correction has been applied, then this field shall contain 0.0.

Time variable frequency offsets. The FREQ.VAR column shall contain an array of time-variable frequency offsets that were applied. There shall be one entry for every band in the file and each entry shall contain the additional frequency offsets applied to the band as a function of time.

Phase and group delay polynomials. The GDELAY_1 and GDELAY_2 columns shall contain polynomial terms for the group delays for each band in polarization 1 and 2, respectively. The group delay is calculated from these according to Eq. 8, where Δt is the number of seconds that have elapsed since the beginning of the interval covered by the model and p_i is the polynomial term with index i for the current band.

$$\tau_g = \sum_{i=1}^{n_{poly}} p_i \cdot (\Delta t)^{i-1} \ . \tag{8}$$

The PDELAY_1 and PDELAY_2 columns shall contain the polynomial terms for the phase delay evaluated at the reference frequency for each band in the same format.

Phase and group delay rates. The GRATE_1 and GRATE_2 columns shall contain polynomial terms for the group delay rates (*i.e.*, the time derivatives of the group delays) for each band in polarizations 1 and 2, respectively. Similarly, the PRATE_1 and PRATE_2 columns shall contain the polynomial terms for the phase delay rates. The same conventions are used as for the group delay terms. Note that the rate terms may be expected to be approximately equal to the delay terms but shifted by one position, but that exact equivalence is not required. This allows for correlators such as the VLBA which model delay and rate separately.

Dispersive delays. The DISP_1 and DISP_2 columns shall contain the components of the group delays for polarization 1 and 2 that scale with the square of the wavelength (*e.g.*, ionospheric delay). These shall be specified by giving the delays in seconds per meter squared. The DDISP_1 and DDISP_2 columns give the time derivatives of the dispersive delays in DISP_1 and DISP_2.

Table revision 1 of the INTERFEROMETER_TABLE differs from table revision 2 in the spelling of column labels from PDELAY_1 through DDISP_2. In revision 1, the underscore character in each was replaced with a blank character.

10 The SYSTEM_TEMPERATURE table

The SYSTEM_TEMPERATURE table contains a record of system and antenna temperatures for the antennæ used in the FITS-IDI file. SYSTEM_TEMPERATURE tables are optional.

10.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 28.

TABLE 28: Mandatory keywords for SYSTEM_TEMPERATURE table headers

Keyword	Value type	Value
EXTNAME	A	'SYSTEM_TEMPERATURE'
TABREV	I	1
NO_POL	I	Number of polarizations in the table

Number of polarizations. If the table contains information for two polarizations, the value of NO_POL keyword shall be 2. If the table only contains information for one polarization, then the value of the NO_POL keyword shall be 1.

10.2 Table structure

Each row contains system temperatures and antenna temperatures for a single antenna using a single frequency setup and that is valid for a limited range of times. Each row shall contain the columns shown in Table 29 above the horizontal line. Columns for the second polarization, listed below the horizontal line, must also appear but only if the value of the NO_POL keyword is two. The columns may be written in any order.

TABLE 29: Mandatory columns for the SYSTEM_TEMPERATURE table

Title	Type	Units	Description
TIME	1D	days	Central time of interval
TIME_INTERVAL	1E	days	Duration of interval
SOURCE_ID	1J		Source ID number
ANTENNA_NO	1J		Antenna number
ARRAY	1J		Array number
FREQID	1J		Frequency setup number
TSYS_1	E(n_{band})	Kelvin	System temperatures for polarization 1
TANT_1	E(n_{band})	Kelvin	Antenna temperatures for polarization 1
TSYS_2	E(n_{band})	Kelvin	System temperatures for polarization 2
TANT_2	E(n_{band})	Kelvin	Antenna temperatures for polarization 2

Time covered by the row. The TIME column shall contain the number of days that have elapsed between 0 hours on the reference date for the current array and the center of the time period covered by the current row. The TIME_INTERVAL column shall contain the number of days covered by the current row.

Source identification number. The SOURCE_ID column shall contain the source identification number of the source to which the current row applies.

Antenna identification. The ANTENNA_NO column shall contain the antenna identification number and the ARRAY column shall contain the array number of the antenna to which the current row applies.

Frequency setup number. The FREQID column shall contain the frequency setup number of the frequency setup to which the current row applies.

System temperatures. The TSYS_1 and TSYS_2 columns shall contain arrays for polarizations 1 and 2, respectively, of system temperatures, one for each band in the current file. If system temperature information is not available for any band in either polarization, then the corresponding elements of the arrays shall be set to NaN.

Antenna temperatures. The TANT_1 and TANT_2 columns shall contain arrays for polarizations 1 and 2, respectively, of antenna temperatures, one for each band in the current file. If antenna temperature information is not available for any band in either polarization, then the corresponding elements of the arrays shall be set to NaN.

11 The GAIN_CURVE table

The GAIN_CURVE table contains tabulated or parameterized gain curve information for the antennæ used in the FITS-IDI file. It is an optional table.

11.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 30.

TABLE 30: Mandatory keywords for GAIN_CURVE table headers

Keyword	Value type	Value
EXTNAME	A	'GAIN_CURVE'
TABREV	I	1
NO_POL	I	Number of polarizations in the table
NO_TABS	I	Number of tabulated values n_{tab}

Number of polarizations. If the table contains information for two polarizations, the value of NO_POL keyword shall be 2. If the table only contains information for one polarization, then the value of the NO_POL keyword shall be 1.

Number of tabulated values. The value of the NO_TABS keyword shall be the maximum number of tabulated values or parameters for a gain curve in the table. This shall be a positive integer.

11.2 Table structure

Each row contains gain information for a single antenna using a single frequency setup. Each row shall contain the columns shown in Table 31 above the horizontal line. Columns for the second polarization, listed below the horizontal line, must also appear but only if the value of the NO_POL keyword is two. The columns may be written in any order.

TABLE 31: Mandatory columns for the GAIN_CURVE table

Title	Type	Units	Description
ANTENNA_NO	1J		Antenna number
ARRAY	1J		Array number
FREQID	1J		Frequency setup number
TYPE_1	J(n_{band})		Gain curve types for polarization 1
NTERM_1	J(n_{band})		Number of terms or entries for polarization 1
X_TYP_1	J(n_{band})		x value types for polarization 1
Y_TYP_1	J(n_{band})		y value types for polarization 1
X_VAL_1	E(n_{band})		x values for polarization 1
Y_VAL_1	E(n_{tab},n_{band})		y values for polarization 1
GAIN_1	E(n_{tab},n_{band})		Relative gain values for polarization 1
SENS_1	E(n_{band})	K/Jy	Sensitivities for polarization 1
TYPE_2	J(n_{band})		Gain curve types for polarization 2
NTERM_2	J(n_{band})		Number of terms or entries for polarization 2
X_TYP_2	J(n_{band})		x value types for polarization 2
Y_TYP_2	J(n_{band})		y value types for polarization 2
X_VAL_2	E(n_{band})		x values for polarization 2
Y_VAL_2	E(n_{tab},n_{band})		y values for polarization 2
GAIN_2	E(n_{tab},n_{band})		Relative gain values for polarization 2
SENS_2	E(n_{band})	K/Jy	Sensitivities for polarization 2

Antenna identification. The ANTENNA_NO column shall contain the antenna identification number and the ARRAY column shall contain the array number of the antenna to which the current row applies.

Frequency setup number. The FREQID column shall contain the frequency setup number of the frequency setup to which the current row applies.

11.3 Gain curve encoding

A separate gain curve shall be provided for each band in each polarization. Each gain curve may be provided as a list of tabulated values, as a polynomial in a single variable, or as a spherical harmonic expansion in hour angle and co-declination (90° - declination) as used by the Green Bank 140-foot telescope. The type of gain curve provided is indicated by the value of the TYPE_1 and TYPE_2 array corresponding to the band: code 1 for tabulated, 2 for polynomial, and 3 for spherical harmonic. Different types of gain curve may be provided for different bands.

In each case, the gain curves are dimensionless and should be multiplied by the sensitivity for the corresponding band to obtain the actual gain. The sensitivities for each band are listed in the SENS_1 and SENS_2 columns, indexed by band number.

11.3.1 Tabulated gain curves

If the gain curve for a given band is tabulated, then the number of tabulated values shall be given in the NTERM_1 or NTERM_2 column for the band, depending on polarization. This shall be a positive number and shall not be greater than n_{tab}. The variable against which the gain values are tabulated shall be indicated by the value in Y_TYP_1 or Y_TYP_2 column for the corresponding band and polarization as shown in Table 32.

TABLE 32: Types for x and y values

Code	Value type
0	None
1	Elevation in degrees
2	Zenith angle in degrees
3	Hour angle in degrees
4	Declination in degrees
5	Co-declination in degrees

The values against which the gain is tabulated shall be listed in the first elements of the Y_VAL_1 or Y_VAL_2 matrix column that corresponds to the band and the gain values shall be listed in the corresponding entries of the GAIN_1 or GAIN_2 matrices. Unused entries in the Y_VAL_1, Y_VAL_2, GAIN_1, and GAIN_2 arrays shall be set to NaN.

If the gain curve is tabulated against hour angle, then the entry in the X_TYP_1 or X_TYP_2 column array for the band shall be 4 (declination) and the corresponding entry in the X_VAL_1 or X_VAL_2 column array shall be the declination at which the gain curve is tabulated in degrees. In all other cases, the X_TYP_1 or X_TYP_2 column array entry shall be zero and the X_VAL_1 or X_VAL_2 column array entry shall be NaN.

11.3.2 Polynomial gain curves

If the gain curve for a given band is polynomial, then the value in the Y_TYP_1 or Y_TYP_2 column array corresponding to the band shall designate the polynomial variable as shown in Table 32 and the value in the NTERM_1 or NTERM_2 column array corresponding to the band shall be the number of terms in the polynomial. This must be a positive number, but may not be larger than n_{tab}. The polynomial coefficients shall be listed in the first elements in the GAIN_1 or GAIN_2 column array that corresponds to the band and starting with the coefficient of the zeroth-order term. Unused elements in GAIN_1 and GAIN_2 column arrays shall be set to 0.0 or to NaN.

If the gain curve is a polynomial of hour angle, then the value of X_TYP_1 or X_TYP_2 column array that corresponds to the band shall be set to 4 and the corresponding element in the X_VAL_1 or X_VAL_2 column array shall be the declination at which the gain curve is evaluated. In all other cases, the X_TYP_1 or X_TYP_2 column array entry shall be zero and the X_VAL_1 or X_VAL_2 column array entry shall be NaN.

All entries in the Y_VAL_1 and Y_VAL_1 column arrays corresponding to the band shall be NaN.

11.3.3 Spherical harmonics

If the gain curve for a band is a spherical harmonic, then the value in the NTERM_1 or NTERM_2 column array corresponding to the band shall be the number of terms in the expansion. This must be a positive number, but may not be larger than n_{tab}. The first elements of the GAIN_1 or GAIN_2 column matrix that corresponds to the band shall hold the coefficients of the harmonic expansion as listed in Table 33.

TABLE 33: Spherical harmonic coefficients in GAIN_1 and GAIN_2

Index	Coefficient
1	A00
2	A10
3	A11E
4	A11O
5	A20
6	A21E
7	A21O
8	A22E
9	A22O
10	A30

The value in the X_TYP_1 or X_TYP_2 column array corresponding to the band shall be 5 (co-declination) and the corresponding value in the Y_TYP_1 or Y_TYP_2 column array shall be 3 (hour angle). All entries in the X_VAL_1 and Y_VAL_1 or X_VAL_2 and Y_VAL_2 column arrays that correspond to the band shall be set to NaN.

12 The PHASE-CAL table

The PHASE-CAL[5] table contains the phase calibration data. It is an optional table.

12.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 34.

TABLE 34: Mandatory keywords for PHASE-CAL table headers

Keyword	Value type	Value
EXTNAME	A	'PHASE-CAL'
TABREV	I	2
NO_POL	I	Number of polarizations in the table
NO_TABS	I	Number of tones n_{tone}

Number of polarizations. If the table contains information for two polarizations, the value of NO_POL keyword shall be 2. If the table only contains information for one polarization, then the value of the NO_POL keyword shall be 1.

Number of tones. The value of the NO_TONES keyword shall be the maximum number of phase-cal tones in a single band. This must be a positive number.

12.2 Table structure

Each row contains phase-cal data for a single antenna using a single frequency setup over a limited period of time. Each row shall contain the columns shown in Table 35 above the horizontal line. Columns for the second polarization, listed below the horizontal line, must also appear but only if the value of the NO_POL keyword is two. The columns may be written in any order.

[5] Note that the table name contains a hyphen rather than an underscore.

TABLE 35: Mandatory columns for the PHASE-CAL table

Title	Type	Units	Description
TIME	1D	days	Central time of interval
TIME_INTERVAL	1E	days	Duration of interval
SOURCE_ID	1J		Source ID number
ANTENNA_NO	1J		Antenna number
ARRAY	1J		Array number
FREQID	1J		Frequency setup number
CABLE_CAL	1D	seconds	Cable calibration measurement
STATE_1	E(4,n_{band})	percent	State counts for polarization 1
PC_FREQ_1	D(n_{tone},n_{band})	Hz	Phase-cal tone frequencies for polarization 1
PC_REAL_1	E(n_{tone},n_{band})		Real parts of phase-cal measurements for polarization 1
PC_IMAG_1	E(n_{tone},n_{band})		Imaginary parts of phase-cal measurements for polarization 1
PC_RATE_1	E(n_{tone},n_{band})	sec/sec	Phase-cal rates for polarization 1
STATE_2	E(4,n_{band})	percent	State counts for polarization 2
PC_FREQ_2	D(n_{tone},n_{band})	Hz	Phase-cal tone frequencies for polarization 2
PC_REAL_2	E(n_{tone},n_{band})		Real parts of phase-cal measurements for polarization 2
PC_IMAG_2	E(n_{tone},n_{band})		Imaginary parts of phase-cal measurements for polarization 2
PC_RATE_2	E(n_{tone},n_{band})	sec/sec	Phase-cal rates for polarization 2

Time covered by the row. The TIME column shall contain the number of days that have elapsed between 0 hours on the reference date for the current array and the center of the time period covered by the current row. The TIME_INTERVAL column shall contain the number of days covered by the current row.

Source identification number. The SOURCE_ID column shall contain the source identification number of the source to which the current row applies.

Antenna identification. The ANTENNA_NO column shall contain the antenna identification number and the ARRAY column shall contain the array number of the antenna to which the current row applies.

Frequency setup number. The FREQID column shall contain the frequency setup number of the frequency setup to which the current row applies.

Cable calibration. The CABLE_CAL column shall contain the measured cable cal value in seconds. If this is not available, then the column shall contain a NaN.

State counts. The STATE_1 and STATE_2 columns shall contain the percentage of time that the digitizer spent in each of its lowest, medium-low, medium-high, and highest states for each band. Entries where these data are not available shall be set to NaN.

Phase-cal tone frequencies. The PC_FREQ_1 and PC_FREQ_2 columns shall list the sky frequencies of the phase-cal tones for each band. Unused entries in these columns shall be set to NaN.

Phase-cal measurements. The phase-cal measurements shall be reported as complex quantities with the real parts listed in PC_REAL_1 and PC_REAL_2 columns and the imaginary parts listed in PC_IMAG_1 and PC_IMAG_2 columns. The PC_RATE_1 and PC_RATE_2 columns shall list the rates of change of the phase cal phase over the interval covered by the record. Unused entries in these columns shall be set to NaN as shall entries corresponding to missing data.

Table revision 1 of the PHASE-CAL table named the polarization-dependent columns with a blank character rather than the second underscore character.

13 The FLAG table

The FLAG table designates data included in the UV_DATA table that are to be regarded a priori as invalid. It is an optional table.

13.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 36.

TABLE 36: Mandatory keywords for FLAG table headers

Keyword	Value type	Value
EXTNAME	A	'FLAG'
TABREV	I	2

13.2 Table structure

Each row in the table specifies a set of data to be flagged. These specifications are independent and may overlap. The table may be regarded as specifying a set of data to be flagged which is the union of the sets specified by its constituent rows. The table shall contain the columns shown in Table 37. The columns may be written in any order.

TABLE 37: Mandatory columns for the FLAG table

Title	Type	Units	Description
SOURCE_ID	1J		Source ID number
ARRAY	1J		Array number
ANTS	2J		Antenna numbers
FREQID	1J		Frequency setup number
TIMERANG	2E	days	Time range
BANDS	J(n_{band})		Band flags
CHANS	2J		Channel range
PFLAGS	4J		Polarization flags
REASON	nA		Reason for flag
SEVERITY	1J		Severity code

Source identification. If the SOURCE_ID column contains a non-zero value, then all data for the source with the ID number matching this value that match the other criteria specified by the current row should be flagged. If the SOURCE_ID column contains a zero value, then all data matching the other criteria specified by the current row should be flagged regardless of the the source number identification.

Array number. If the ARRAY column contains a non-zero value, then all data from the array with this array number that match the other criteria specified by the current row should be flagged. If the ARRAY column contains a zero value, then all data matching the other criteria specified by the current row should be flagged regardless of the array number.

Antennæ. If both elements of the ANTS column are zero, then all data that match the other criteria specified by the current row should be flagged regardless of the baseline from which they were obtained. If the first element of the ANTS column is positive and the second element is zero, then all data that match the other criteria specified by the current row and that are obtained from baselines involving the antenna with the antenna identification number given in the first element should be flagged. If both elements of the ANTS column are positive, then all data that match the other criteria specified by the current row and that are obtained from the baseline defined by the antennæ with identification numbers given by the first and second elements should be flagged.

Frequency setup number. If the FREQID column contains a positive number, then all data taken with the setup that has been assigned this frequency setup number, and that match the other criteria specified by the current row, should be flagged. If it has the value of 0 or −1, then all data that match the other criteria specified by the current row should be flagged regardless of frequency setup.

Band flags. If the entry in the BANDS column that corresponds to a given band number is not zero, then all data for this band that meet the other criteria specified by the current row should be flagged. If the entry in the BANDS column that corresponds to a given band number is zero, then the current row specifies no flags for this band.

Channel range. Data from channels with numbers in the range specified by the two elements in the CHANS column that meet the other criteria specified by the current row should be flagged. The first element shall be less than or equal to the second element in the CHANS column. If both elements of the CHANS column are zero, then the channel range is taken to cover all channels.

Polarization flags. If an element in the PFLAGS column is not zero, then all data that have the corresponding index on the STOKES axis of the data matrix and that meet the other criteria specified by the current row should be flagged.

Reason. the REASON column shall contain a short string explaining why the data specified by the current record were flagged. Flatters[2] specified the length as 24 characters, probably because that is the internal length in the AIPS software. There is no reason to limit the length and FITS-IDI readers should be able to cope with any length up to 80 characters. The VLBA uses 40.

Severity code. The SEVERITY column shall contain a severity code that applies to the current record. Recommended code are listed in Table 38. Software may use the severity codes to decide whether to apply the flags specified by individual rows in the FLAG table.

TABLE 38: Recommended SEVERITY codes

Code	Severity level
−1	No severity level assigned
0	Data are known to be useless
1	Data are probably useless
2	Data may be useless

Revision 2 FLAG tables differ from revision 1 tables in using an array of flags to specify the bands that should be flagged. In revision 1 tables, the BANDS field contained a two-element array of integers that specified a contiguous range of band numbers to be flagged.

14 The WEATHER table

The WEATHER table contains meteorological data for the antennæ and times used in the FITS-IDI file.

14.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 39.

TABLE 39: Mandatory keywords for WEATHER table headers

Keyword	Value type	Value
EXTNAME	A	'WEATHER'
TABREV	I	3
RDATE	D	Reference date

Reference date. The value of the RDATE parameter will be the date for which the time system parameters apply.

14.2 Table structure

Each row contains meteorological data for a single antenna (or all antennæ) over a limited period of time. Each row shall contain the columns shown in Table 40. The columns may be written in any order. If a value for some parameter is unavailable, it shall be written as NaN.

Time covered by the row. The TIME column shall contain the number of days that have elapsed between 0 hours on the reference date for the current array and the center of the time period covered by the current row. The TIME_INTERVAL column shall contain the number of days covered by the current row.

TABLE 40: Mandatory and optional columns for the WEATHER table

Title	Type	Units	Description
TIME	1D	days	Central time of interval
TIME_INTERVAL	1E	days	Duration of interval
ANTENNA_NO	1J		Antenna number
TEMPERATURE	1E	Centigrade	Surface air temperature
PRESSURE	1E	millibar	Surface air pressure
DEWPOINT	1E	Centigrade	Dewpoint temperature
WIND_VELOCITY	1E	m s^{-1}	Wind velocity
WIND_DIRECTION	1E	degrees	Wind direction East from North
WIND_GUST	1R	m s^{-1}	Wind gust speed
PRECIPITATION	1R	cm	Precipitation since midnight local time
WVR_H2O	1E	m^{-2}	Water column
IONOS_ELECTRON	1E	m^{-2}	Electron column

Antenna identification. The ANTENNA_NO column shall contain the antenna identification number of the antenna to which the current row applies. If the value of the ANTENNA_NO column is zero, the data in the row are understood to apply to all antennæ.

Weather information. The surface TEMPERATURE, PRESSURE, and DEWPOINT shall be given in the common units of degrees Centigrade and millibars. The WIND_VELOCITY in meters per second and the WIND_DIRECTION in degrees measured to the East from North shall also be given. Optional parameters WIND_GUST giving the gusty wind speed in meters per second and PRECIPITATION giving the amount of preciptable water accumulated since midnight local time in cm are also understood and may be present.

Atmospheric absorbers. Optional columns in the table include the column of precipitable water above the telescope in molecules per meter squared and the column of ionospheric electrons per meter squared shall be given in the WVR_H2O and IONOS_ELECTRON, respectively.

Table revision 1 of the WEATHER table spelled many of the column labels differently. In the order of Table 40, they were 'TIME', 'TIME INTERVAL', 'ANTENNA NUMBER', 'TEMPERATURE', 'PRESSURE', 'DEWPOINT', 'WIND VELOCITY', 'WIND DIRECTION', 'H2O COLUMN', and 'ELECTRON COLUMN'.

15 The BASELINE table

The BASELINE table contains baseline-dependent multiplicative and additive corrections.

15.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 41.

TABLE 41: Mandatory keywords for BASELINE table headers

Keyword	Value type	Value
EXTNAME	A	'BASELINE'
TABREV	I	1
NO_ANT	I	Maximum antenna number in the table

Number of antennæ. The NO_ANT keyword shall have value equal to the maximum antenna number appearing in the table.

Number of Stokes parameters. The number of Stokes parameters shall be set by the value of the required keyword NO_STKD. It shall be equal to the number of pixels on the STOKES axis in the regular data matrix of the UV_DATA table.

15.2 Table structure

Each row contains baseline-dependent corrections for one baseline, source, and frequency setup. Each row shall contain the columns shown in Table 42. The columns may be written in any order.

TABLE 42: Mandatory columns for the BASELINE table

Title	Type	Units	Description
TIME	1D	days	Central time of interval
SOURCE_ID	1J		Source ID number
ARRAY	1J		Array number
ANTENNA_NOS.	2J		Antenna numbers forming baseline
FREQID	1J		Frequency setup number
REAL_M	E(n_{stokes},n_{band})		Real part of multiplicative correction
IMAG_M	E(n_{stokes},n_{band})		Imaginary part of multiplicative correction
REAL_A	E(n_{stokes},n_{band})		Real part of additive correction
IMAG_A	E(n_{stokes},n_{band})		Imaginary part of additive correction

Time covered by the row. The TIME column shall contain the number of days that have elapsed between 0 hours on the reference date for the current array and the center of the time period covered by the current row. If the BASELINE table contains more than one row with identical values in the SOURCE_ID, ARRAY, ANTENNA_NOS., and FREQID columns, then the multiplicative and additive constants are to be interpolated to times between the times in the TIME column and extrapolated to times outside the range of times in the TIME column.

Source identification number. The SOURCE_ID column shall contain the source identification number of the source to which the current row applies. A value of zero in the SOURCE_ID column shall be understood to apply to all source identification numbers.

Baseline identification. The ANTENNA_NOS. column shall contain the two antenna identification numbers forming the baseline and the ARRAY column shall contain the array number to which the current row applies. (Note the period at the end of column name.)

Frequency setup number. The FREQID column shall contain the frequency setup number of the frequency setup to which the current row applies.

Calibration data. The multiplicative correction M is a complex quantity whose real parts are in the matrix contained in the REAL_M column and whose imaginary parts are in the matrix contained in the IMAG_M column. The additive correction A is a complex quantity whose real parts are in the matrix contained in the REAL_A column and whose imaginary parts are in the matrix contained in the IMAG_A column. Each of these four matrices are dimensioned by (n_{stokes},n_{band}). To apply the corrections, the visibility data for the selected baseline and source should first be multiplied by M and then have A added.

Special note. The AIPS implementation of this table does not support the full generality described here. FITLD will translated the BASELINE table into an AIPS BL table containing at most two, parallel-hand polarizations. The routines which apply the correction ignore the additive term.

16 The BANDPASS table

The BANDPASS table contains the antenna-based, spectral-channel dependent calibrations. Each row of the table contains one complex gain for each spectral channel. Parameterized solutions for the bandpass must be expanded to this form, avoiding the difficulties associated with defining the functional forms for which the parameterization applies.

16.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 43.

TABLE 43: Mandatory keywords for BANDPASS table headers

Keyword	Value type	Value
EXTNAME	A	'BANDPASS'
TABREV	I	1
NO_ANT	I	Maximum antenna number in the table
NO_POL	I	Number of polarizations in the table
NO_BACH	I	Number of spectral channels in the table
STRT_CHN	I	Data channel number for first channel in the table

Number of antennæ. The NO_ANT keyword shall have value equal to the maximum antenna number appearing in the table.

Number of polarizations. If the table contains information for two polarizations, the value of NO_POL keyword shall be 2. If the table only contains information for one polarization, then the value of the NO_POL keyword shall be 1.

Number of spectral channels. The number of spectral channels in the BANDPASS table shall be set by the value of the NO_BACH keyword n_{bach}. It shall be a positive integer less than or equal the value of the standard keyword NO_CHAN n_{chan}. The n_{bach} channels are taken to apply to spectral channels in the UV_DATA regular matrices from pixel n_0 through $n_0+ n_{bach} -1$, where n_0 is the value of the keyword STRT_CHN. The value of STRT_CHN must be ≥ 1 and small enough that $n_0+ n_{bach} -1 \leq n_{chan}$.

16.2 Table structure

Each row contains spectral-channel-dependent corrections for one antenna, source, and frequency setup for a limited range of time. Each row shall contain the columns shown in Table 44 above the horizontal line. Columns for the second polarization, listed below the horizontal line, must also appear but only if the value of the NO_POL keyword is two. The columns may be written in any order.

TABLE 44: Mandatory columns for the BANDPASS table

Title	Type	Units	Description
TIME	1D	days	Central time of interval
TIME_INTERVAL	1E	days	Duration of interval
SOURCE_ID	1J		Source ID number
ANTENNA_NO	1J		Antenna number
ARRAY	1J		Array number
FREQID	1J		Frequency setup number
BANDWIDTH	1E	Hz	Channel bandwidth
BAND_FREQ	D(n_{band})	Hz	Frequency of each band
REFANT_1	1J		Reference antenna for polarization 1
BREAL_1	E(n_{bach},n_{band})		Real part of bandpass correction for polarization 1
BIMAG_1	E(n_{bach},n_{band})		Imaginary part of bandpass correction for polarization 1
REFANT_2	1J		Reference antenna for polarization 2
BREAL_2	E(n_{bach},n_{band})		Real part of bandpass correction for polarization 2
BIMAG_2	E(n_{bach},n_{band})		Imaginary part of bandpass correction for polarization 2

Time covered by the row. The TIME column shall contain the number of days that have elapsed between 0 hours on the reference date for the current array and the center of the time period covered by the current row. The TIME_INTERVAL column shall contain the number of days covered by the current row.

Source identification number. The SOURCE_ID column shall contain the source identification number of the source to which the current row applies. A value of zero in the SOURCE_ID column shall be understood to apply to all source identification numbers.

Antenna identification. The ANTENNA_NO column shall contain the antenna identification number and the ARRAY column shall contain the array number of the antenna to which the current row applies.

Frequency information. The FREQID column shall contain the frequency setup number of the frequency setup to which the current row applies. The BANDWIDTH column shall contain the individual channel separation in Hz of the first band in this frequency setup. The BAND_FREQ column contains the reference frequencies for each band in this frequency setup.

Reference antenna. The phase of the bandpass function for the "reference antenna" is by convention equal to zero for all channels and all other phases are with respect to this reference. The antenna used as the reference for polarization 1 shall be recorded in the REFANT_1 column and the antenna used as the reference for polarization 2, if there are two polarizations, shall be recorded in the REFANT_2 column.

Bandpass function. The complex visibilities for baseline $i - j$ are corrected by dividing by the bandpass function for antenna i and dividing by the complex conjugate of the bandpass function for antenna j. The bandpass function for polarization 1 is given in the BREAL_1 column for the real part and the BIMAG_1 column for the imaginary part. If the value of the keyword NO_POL is two, the real part of the bandpass function for polarization 2 is given in the BREAL_2 column and the imaginary part is given in the BIMAG_2 column.

17 The CALIBRATION table

This chapter is included for documentation and discussion purposes only. So far as this author is aware, no software has been implemented to either write or read the CALIBRATION table. Therefore, the description provided in this section should be regarded as tentative. In fact, it is not at all clear what the intentions were in the case of some of the columns specified for this table.

17.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 45.

TABLE 45: Mandatory keywords for CALIBRATION table headers

Keyword	Value type	Value
EXTNAME	A	'CALIBRATION'
TABREV	I	1
NO_ANT	I	Maximum antenna number in the table
NO_POL	I	Number of polarizations in the table

Number of antennæ. The NO_ANT keyword shall have value equal to the maximum antenna number appearing in the table.

Number of polarizations. If the table contains information for two polarizations, the value of NO_POL keyword shall be 2. If the table only contains information for one polarization, then the value of the NO_POL keyword shall be 1.

17.2 Table structure

Each row contains data corrections for one antenna, source, and frequency setup for a limited range of time. Each row shall contain the columns shown in Table 46 above the horizontal line. Columns for the second polarization, listed below the horizontal line, must also appear but only if the value of the NO_POL keyword is two. The columns may be written in any order.

Time covered by the row. The TIME column shall contain the number of days that have elapsed between 0 hours on the reference date for the current array and the center of the time period covered by the current row. The TIME_INTERVAL column shall contain the number of days covered by the current row.

Source identification number. The SOURCE_ID column shall contain the source identification number of the source to which the current row applies. A value of zero in the SOURCE_ID column shall be understood to apply to all source identification numbers.

Antenna identification. The ANTENNA_NO column shall contain the antenna identification number and the ARRAY column shall contain the array number of the antenna to which the current row applies.

Frequency setup number. The FREQID column shall contain the frequency setup number of the frequency setup to which the current row applies.

TABLE 46: Mandatory columns for the CALIBRATION table

Title	Type	Units	Description
TIME	1D	days	Central time of interval
TIME_INTERVAL	1E	days	Duration of interval
SOURCE_ID	1J		Source ID number
ANTENNA_NO	1J		Antenna number
ARRAY	1J		Array number
FREQID	1J		Frequency setup number
TSYS_1	E(n_{band})	Kelvin	System temperature for polarization 1
TANT_1	E(n_{band})	Kelvin	Antenna temperature for polarization 1
SENSITIVITY_1	E(n_{band})	Kelvin/Jy	Sensitivity at polarization 1
PHASE_1	E(n_{band})	radians	Phase at polarization 1
RATE_1	E(n_{band})	sec/sec	Rate of change of delay of polarization 1
DELAY_1	E(n_{band})	seconds	Delay of polarization 1
REAL_1	E(n_{band})		Complex gain real part for polarization 1
IMAG_1	E(n_{band})		Complex gain imaginary part for polarization 1
WEIGHT_1	E(n_{band})		Reliability weight of complex gain for polarization 1
REFANT_1	J(n_{band})		Reference antenna for polarization 1
TSYS_2	E(n_{band})	Kelvin	System temperature for polarization 2
TANT_2	E(n_{band})	Kelvin	Antenna temperature for polarization 2
SENSITIVITY_2	E(n_{band})	Kelvin/Jy	Sensitivity at polarization 2
PHASE_2	E(n_{band})	radians	Phase at polarization 2
RATE_2	E(n_{band})	sec/sec	Rate of change of delay of polarization 2
DELAY_2	E(n_{band})	seconds	Delay of polarization 2
REAL_2	E(n_{band})		Complex gain real part for polarization 2
IMAG_2	E(n_{band})		Complex gain imaginary part for polarization 2
WEIGHT_2	E(n_{band})		Reliability weight of complex gain for polarization 2
REFANT_2	J(n_{band})		Reference antenna for polarization 2

System temperatures. The TSYS_1 and TSYS_2 columns shall contain arrays for polarizations 1 and 2, respectively, of system temperatures, one for each band in the current file. The TSYS_2 column shall appear if and only if the value of the NO_POL keyword is 2. If system temperature information is not available for any band in either polarization, then the corresponding elements of the arrays shall be set to NaN.

Antenna temperatures. The TANT_1 and TANT_2 columns shall contain arrays for polarizations 1 and 2, respectively, of antenna temperatures, one for each band in the current file. The TANT_2 column shall appear if and only if the value of the NO_POL keyword is 2. If antenna temperature information is not available for any band in either polarization, then the corresponding elements of the arrays shall be set to NaN.

Sensitivities. The SENSITIVITY_1 and SENSITIVITY_2 columns shall contain arrays for polarizations 1 and 2, respectively, of sensitivities (degrees Kelvin of antenna temperature produced by a 1 Jy source), one for each band in the current file. The SENSITIVITY_2 column shall appear if and only if the value of the NO_POL keyword is 2. If sensitivity information is not available for any band in either polarization, then the corresponding elements of the arrays shall be set to NaN.

Antenna phase. The PHASE_1 and PHASE_2 columns shall contain arrays for polarizations 1 and 2, respectively, of antenna phase in radians, one for each band in the file. Similarly, the DELAY_1 and DELAY_2 columns shall contain the antenna delays and the RATE_1 and RATE_2 columns shall contain the rate of change of antenna delays. The PHASE_2, DELAY_2, and RATE_2 columns shall appear if and only if the value of the NO_POL keyword is 2. If any of these data are no available, the the corresponding elements of the arrays shall be set to NaN.

Complex gain. The REAL_1 and IMAG_1 columns shall provide the real and imaginary parts, respectively, of the complex gain in polarization 1 for each band in the array. If and only if the value of the keyword NO_POL is 2, the REAL_2 and IMAG_2 columns shall provide the real and imaginary parts, respectively, of the complex gain in polarization 2 for each band in the array. The WEIGHT_1 and WEIGHT_2 columns shall provide some indication of the relative reliability of the complex gain solutions. These data may be used when averaging or interpolating complex gains over time.

Reference antenna. The phase of the complex gain for the "reference antenna" is by convention zero and all other phases are with respect to this reference. The antenna used as the reference for polarization 1 shall be recorded in the REFANT_1 column and the antenna used as the reference for polarization 2, if there are two polarizations, shall be recorded in the REFANT_2 column.

18 The MODEL_COMPS table

The MODEL_COMPS table is one of those reserved for use by the VLBA. However, since it has been used fairly widely, it will be documented here. It is used to convey the parameters of the spectral sampling and of the various delay corrections applied to the data during the correlation.

18.1 Table header

The table header shall contain all normal FITS binary table keywords needed to characterize the table fully, the mandatory, common keywords of Table 11 discussed on page 12, plus the keywords and values listed in Table 47.

TABLE 47: Mandatory keywords for MODEL_COMPS table headers

Keyword	Value type	Value
EXTNAME	A	'MODEL_COMPS'
TABREV	I	1
RDATE	D	Reference date
NO_POL	I	Number of polarizations in the table
FFT_SIZE	I	FFT size
OVERSAMP	I	Oversampling factor
ZERO_PAD	I	Zero padding factor
TAPER_FN	A	Tapering function ('HANNING' or 'UNIFORM')
DELTAT	E	Time interval (days)

Reference date. The value of the RDATE parameter will be the date for which the time system parameters apply.

Number of polarizations. If the table contains information for two polarizations, the value of NO_POL keyword shall be 2. If the table only contains information for one polarization, then the value of the NO_POL keyword shall be 1.

Data sampling. The data are given for an antenna and one or more sources every DELTAT days and apply until the next recorded time. The numerical size of the FFT used to convert from time domain to frequency prior to cross-correlation shall be specified in the FFT_SIZE keyword. Its value is normally an integer power of 2. The oversampling and zero padding "factors" are given by the OVERSAMP and ZERO_PAD keywords; a value of 0 for these keywords implies no oversampling and no zero padding. The taper if any applied to the time domain prior to FFT is specified in the character-valued keyword TAPER_FN; only 'HANNING' and 'UNIFORM' (no taper) are recognized.

18.2 Table structure

Each row contains the various delays and frequency offsets for one antenna, source, and frequency setup for a limited range of time. Each row shall contain the columns shown in Table 48 above the horizontal line. Columns for the second polarization, listed below the horizontal line, must also appear but only if the value of the NO_POL keyword is two. The columns may be written in any order.

TABLE 48: Mandatory columns for the MODEL_COMPS table

Title	Type	Units	Description
TIME	1D	days	Start time of interval
SOURCE_ID	1J		Source ID number
ANTENNA_NO	1J		Antenna number
ARRAY	1J		Array number
FREQID	1J		Frequency setup number
ATMOS	1D	sec	Atmospheric delay
DATMOS	1D	sec/sec	Time derivative of atmospheric delay
GDELAY	1D	sec	Group delay
GRATE	1D	sec/sec	Rate of change of group delay
CLOCK_1	1D	sec	"Clock" epoch error
DCLOCK_1	1D	sec/sec	Time derivative of clock error
LO_OFFSET_1	E(n_{band})	Hz	LO offset
DLO_OFFSET_1	E(n_{band})	Hz/sec	Time derivative of LO offset
DISP_1	1E	sec m^{-2}	Dispersive delay
DDISP_1	1E	sec m^{-2}/sec	Time derivative of dispersive delay
CLOCK_2	1D	sec	"Clock" epoch error
DCLOCK_2	1D	sec/sec	Time derivative of clock error
LO_OFFSET_2	E(n_{band})	Hz	LO offset
DLO_OFFSET_2	E(n_{band})	Hz/sec	Time derivative of LO offset
DISP_2	1E	sec m^{-2}	Dispersive delay
DDISP_2	1E	sec m^{-2}/sec	Time derivative of dispersive delay

Time covered by the row. The TIME column shall contain the number of days that have elapsed between 0 hours on the reference date for the current array and the beginning of the time period covered by the current row.

Source identification number. The SOURCE_ID column shall contain the source identification number of the source to which the current row applies. A value of zero in the SOURCE_ID column shall be understood to apply to all source identification numbers.

Antenna identification. The ANTENNA_NO column shall contain the antenna identification number and the ARRAY column shall contain the array number of the antenna to which the current row applies.

Frequency information. The FREQID column shall contain the frequency setup number of the frequency setup to which the current row applies.

Atmospheric delay. The ATMOS and DATMOS columns shall contain the atmospheric group phase delay and rate of change of that delay, respectively, applied to the data by the correlator software.

Group delay. The GDELAY and GRATE columns shall contain the group delay calculated by the CALC software and the rate of change of that delay, respectively, applied to the data by the correlator software.

Clock error. The CLOCK_1 and DCLOCK_1 columns shall contain the electronic, clock-like delay and the rate of change of that delay, respectively, applied to the data of polarization 1 by the correlator software. If the value of the NO_POL keyword is two, then the CLOCK_2 and DCLOCK_2 columns shall contain the electronic, clock-like delay and the rate of change of that delay, respectively, applied to the data of polarization 2 by the correlator software.

LO offset. The LO_OFFSET_1 and DLO_OFFSET_1 columns shall contain the station-dependent local oscillator offset and rate of change of that offset, respectively, applied to the data of polarization 1 by the correlator software. If the value of the NO_POL keyword is two, then the LO_OFFSET_2 and DLO_OFFSET_2 columns shall contain the station-dependent local oscillator offset and rate of change of that offset, respectively, applied to the data of polarization 2 by the correlator software.

Dispersive delays. The DISP_1 and DDISP_1 columns shall contain the component of the group delay that scales with the square of the wavelength (*e.g.*, ionospheric delay) and rate of change of that delay, respectively, applied to the data of polarization 1 by the correlator software. These shall be specified by giving the delays in seconds per meter squared. If the value of the NO_POL keyword is two, then the DISP_1 and DDISP_1 columns shall contain the component of the group delay that scales with the square of the wavelength (*e.g.*, ionospheric delay) and rate of change of that delay, respectively, applied to the data of polarization 2 by the correlator software.

References

[1] Diamond, P. J., Benson, J., Cotton, W. D., Wells, D. C., Romney, J. & Hunt, G. 1997, "FITS Format for Interferometry Data Interchange," VLBA Correlator Memo No. 108, NRAO, Socorro, NM

[2] Flatters, C. 1998, "The FITS Interferometry Data Interchange Format," AIPS Memo No. 102, NRAO, Socorro, NM

[3] IAU FITS Working Group 2008, "Definition of the Flexible Image Transport System (FITS)," http://fits.gsfc.nasa.gov/fits_standard.html

[4] "Synthesis Imaging in Radio Astronomy II" 1999, ASP Conf. Series 180, eds. Taylor, G. B., Carilli, C. L., & Perley, R. A., Astronomical Society of the Pacific, San Francisco

[5] Thompson, A. R., Moran, J. M., & Swenson, G. W. 2001, "Interferometry and Synthesis in Radio Astronomy," Second Edition, John Wiley & Sons, New York

A Example FITS-IDI file

The sample FITS headers listed below come from a VLBA correlator output file chosen at random. The only changes made were to (1) omit all HISTORY and commentary card images, (2) add a CORRELAT keyword to the main HDU, and (3) to correct the UU-L, VV-L, WW-L, and ID_NO. errors which the VLBA correlator system makes.

A.1 Primary HDU

```
SIMPLE  =                    T / Standard FITS format
BITPIX  =                    8 /
NAXIS   =                    0 /
EXTEND  =                    T /
BLOCKED =                    T /
OBJECT  = 'BINARYTB'           /
TELESCOP= 'VLBA    '           /
CORELAT = 'VLBA    '           / added to header dump by EWG
FXCORVER= '4.22    '           /
OBSERVER= 'BL146   '           /
ORIGIN  = 'VLBA Correlator'    /
DATE-OBS= '2007-08-23'         /
DATE-MAP= '2007-08-31'         / Correlation date
GROUPS  =                    T /
GCOUNT  =                    0 /
PCOUNT  =                    0 /
END
```

A.2 Binary table headers

```
XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                   64 /
NAXIS2  =                   10 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                    7 /
EXTNAME = 'ARRAY_GEOMETRY'     /
EXTVER  =                    1 /
TTYPE1  = 'ANNAME  '           / station name
TFORM1  = '8A      '           /
TTYPE2  = 'STABXYZ '           / station offset from array origin
TFORM2  = '3D      '           /
TUNIT2  = 'METERS  '           /
TTYPE3  = 'DERXYZ  '           / first order derivs of STABXYZ
TFORM3  = '3E      '           /
TUNIT3  = 'M/SEC   '           /
TTYPE4  = 'ORBPARM '           / orbital parameters
TFORM4  = '0D      '           /
TTYPE5  = 'NOSTA   '           / station id number
TFORM5  = '1J      '           /
TTYPE6  = 'MNTSTA  '           / antenna mount type
TFORM6  = '1J      '           /
TTYPE7  = 'STAXOF  '           / axis offset, x, y, z
TFORM7  = '3E      '           /
```

```
TUNIT7  = 'METERS  '           /
ARRAYX  =   0.00000000000000000E+00 /
ARRAYY  =   0.00000000000000000E+00 /
ARRAYZ  =   0.00000000000000000E+00 /
ARRNAM  = 'VLBA    '           /
NUMORB  =                    0 /
RDATE   = '2007-08-23'         /
FREQ    =   8.40549000000000000E+09 /
FRAME   = 'GEOCENTRIC'         /
TIMSYS  = 'UTC     '           /
TIMESYS = 'UTC     '           /
GSTIA0  =   3.30909596261338038E+02 /
DEGPDY  =   3.60985644973299998E+02 /
POLARX  =   2.08099999999999996E-01 /
POLARY  =   2.80019999999999989E-01 /
UT1UTC  =  -1.63126999999999995E-01 /
IATUTC  =   3.30000000000000000E+01 /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    1 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                  284 /
NAXIS2  =                    6 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   23 /
EXTNAME = 'SOURCE  '           /
EXTVER  =                    1 /
TTYPE1  = 'SOURCE_ID'          / source id number (corrected by EWG)
TFORM1  = '1J      '           /
TTYPE2  = 'SOURCE  '           / source name
TFORM2  = '16A     '           /
TTYPE3  = 'QUAL    '           / source qualifier
TFORM3  = '1J      '           /
TTYPE4  = 'CALCODE '           / calibrator code
TFORM4  = '4A      '           /
TTYPE5  = 'FREQID  '           / freq id number in frequency tbl
TFORM5  = '1J      '           /
TTYPE6  = 'IFLUX   '           / ipol flux density at ref freq
TFORM6  = '4E      '           /
TUNIT6  = 'JY      '           /
TTYPE7  = 'QFLUX   '           / qpol flux density at ref freq
TFORM7  = '4E      '           /
TUNIT7  = 'JY      '           /
TTYPE8  = 'UFLUX   '           / upol flux density at ref freq
TFORM8  = '4E      '           /
TUNIT8  = 'JY      '           /
```

```
TTYPE9  = 'VFLUX   '           / vpol flux density at ref freq
TFORM9  = '4E      '           /
TUNIT9  = 'JY      '           /
TTYPE10 = 'ALPHA   '           / spectral index
TFORM10 = '4E      '           /
TTYPE11 = 'FREQOFF '           / freq. offset from ref freq.
TFORM11 = '4D      '           /
TUNIT11 = 'HZ      '           /
TTYPE12 = 'RAEPO   '           / Right Ascension at EQUINOX (EWG)
TFORM12 = '1D      '           /
TUNIT12 = 'DEGREES '           /
TTYPE13 = 'DECEPO  '           / Declination at EQUINOX (EWG)
TFORM13 = '1D      '           /
TUNIT13 = 'DEGREES '           /
TTYPE14 = 'EQUINOX '           / equinox '1950.0B' or 'J2000' (EWG)
TFORM14 = '8A      '           / corrected from 1D by EWG
TUNIT14 = '        '           / corrected from YEARS by EWG
TTYPE15 = 'RAAPP   '           / apparent RA at 0 IAT ref day
TFORM15 = '1D      '           /
TUNIT15 = 'DEGREES '           /
TTYPE16 = 'DECAPP  '           / apparent Dec at 0 IAT ref day
TFORM16 = '1D      '           /
TUNIT16 = 'DEGREES '           /
TTYPE17 = 'SYSVEL  '           / systemic velocity at ref pixal
TFORM17 = '4D      '           /
TUNIT17 = 'M/SEC   '           /
TTYPE18 = 'VELTYP  '           / velocity type
TFORM18 = '8A      '           /
TTYPE19 = 'VELDEF  '           / velocity def: radio, optical
TFORM19 = '8A      '           /
TTYPE20 = 'RESTFREQ'           / line rest frequency
TFORM20 = '4D      '           /
TUNIT20 = 'HZ      '           /
TTYPE21 = 'PMRA    '           / proper motion in RA
TFORM21 = '1D      '           /
TUNIT21 = 'DEG/DAY '           /
TTYPE22 = 'PMDEC   '           / proper motion in Dec
TFORM22 = '1D      '           /
TUNIT22 = 'DEG/DAY '           /
TTYPE23 = 'PARALLAX'           / parallax of source
TFORM23 = '1E      '           /
TUNIT23 = 'ARCSEC  '           /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    1 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                  102 /
```

```
NAXIS2  =                   10 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   13 /
EXTNAME = 'ANTENNA '           /
EXTVER  =                    1 /
TTYPE1  = 'TIME    '           / time of center of interval
TFORM1  = '1D      '           /
TUNIT1  = 'DAYS    '           /
TTYPE2  = 'TIME_INTERVAL'      / row interval
TFORM2  = '1E      '           /
TUNIT2  = 'DAYS    '           /
TTYPE3  = 'ANNAME  '           / station name
TFORM3  = '8A      '           /
TTYPE4  = 'ANTENNA_NO'         / antenna number
TFORM4  = '1J      '           /
TTYPE5  = 'ARRAY   '           / array id number
TFORM5  = '1J      '           /
TTYPE6  = 'FREQID  '           / frequency id number
TFORM6  = '1J      '           /
TTYPE7  = 'NO_LEVELS'          / number of digitizer levels
TFORM7  = '1J      '           /
TTYPE8  = 'POLTYA  '           / feed A poln. code
TFORM8  = '1A      '           /
TTYPE9  = 'POLAA   '           / feed A position angle
TFORM9  = '4E      '           /
TUNIT9  = 'DEGREES '           /
TTYPE10 = 'POLCALA '           / feed A poln. cal. parameter
TFORM10 = '4E      '           /
TTYPE11 = 'POLTYB  '           / feed B poln. code
TFORM11 = '1A      '           /
TTYPE12 = 'POLAB   '           / feed B position angle
TFORM12 = '4E      '           /
TUNIT12 = 'DEGREES '           /
TTYPE13 = 'POLCALB '           / feed B poln. cal. parameter
TFORM13 = '4E      '           /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    1 /
NOPCAL  =                    0 /
POLTYPE = 'APPROX  '           /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                  100 /
NAXIS2  =                    1 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                    6 /
```

```
EXTNAME = 'FREQUENCY'          /
EXTVER  =                    1 /
TTYPE1  = 'FREQID  '           / FREQID number in uv data
TFORM1  = '1J      '           /
TTYPE2  = 'BANDFREQ'           / frequency offset
TFORM2  = '4D      '           /
TUNIT2  = 'HZ      '           /
TTYPE3  = 'CH_WIDTH'           / spectral channel bandwidth
TFORM3  = '4E      '           /
TUNIT3  = 'HZ      '           /
TTYPE4  = 'TOTAL_BANDWIDTH'    / total bw of a BAND
TFORM4  = '4E      '           /
TUNIT4  = 'HZ      '           /
TTYPE5  = 'SIDEBAND'           / sideband of each BAND
TFORM5  = '4J      '           /
TTYPE6  = 'BB_CHAN '           / baseband channel number (1-16)
TFORM6  = '4J      '           /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    2 /
END


XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                 1024 /
NAXIS2  =                  640 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   20 /
EXTNAME = 'INTERFEROMETER_MODEL' /
EXTVER  =                    1 /
TTYPE1  = 'TIME    '           / time of model start
TFORM1  = '1D      '           /
TUNIT1  = 'DAYS    '           /
TTYPE2  = 'TIME_INTERVAL'      / model interval
TFORM2  = '1E      '           /
TUNIT2  = 'DAYS    '           /
TTYPE3  = 'SOURCE_ID'          / source id from sources tbl
TFORM3  = '1J      '           /
TTYPE4  = 'ANTENNA_NO'         / antenna number from antennas tbl
TFORM4  = '1J      '           /
TTYPE5  = 'ARRAY   '           / array id number
TFORM5  = '1J      '           /
TTYPE6  = 'FREQID  '           / frequency id number from frequency tbl
TFORM6  = '1J      '           /
TTYPE7  = 'I.FAR.ROT'          / ionospheric faraday rotation
TFORM7  = '1E      '           /
TUNIT7  = 'RAD/METER**2'       /
TTYPE8  = 'FREQ.VAR'           / time variable freq. offset
TFORM8  = '4E      '           /
```

```
TUNIT8  = 'HZ      '           /
TTYPE9  = 'PDELAY_1'           / total phase delay at ref time
TFORM9  = '24D     '           /
TUNIT9  = 'TURNS   '           /
TTYPE10 = 'GDELAY_1'           / total group delay at ref time
TFORM10 = '6D      '           /
TUNIT10 = 'SECONDS '           /
TTYPE11 = 'PRATE_1 '           / phase delay rate
TFORM11 = '24D     '           /
TUNIT11 = 'HZ      '           /
TTYPE12 = 'GRATE_1 '           / group delay rate
TFORM12 = '6D      '           /
TUNIT12 = 'SEC/SEC '           /
TTYPE13 = 'DISP_1  '           / dispersive delay for polar.1
TFORM13 = '1E      '           /
TUNIT13 = 'SECONDS '           /
TTYPE14 = 'DDISP_1 '           / dispersive delay rate for polar. 1
TFORM14 = '1E      '           /
TUNIT14 = 'SEC/SEC '           /
TTYPE15 = 'PDELAY_2'           / total phase delay at ref time
TFORM15 = '24D     '           /
TUNIT15 = 'TURNS   '           /
TTYPE16 = 'GDELAY_2'           / total group delay at ref time
TFORM16 = '6D      '           /
TUNIT16 = 'SECONDS '           /
TTYPE17 = 'PRATE_2 '           / phase delay rate
TFORM17 = '24D     '           /
TUNIT17 = 'HZ      '           /
TTYPE18 = 'GRATE_2 '           / group delay rate
TFORM18 = '6D      '           /
TUNIT18 = 'SEC/SEC '           /
TTYPE19 = 'DISP_2  '           / dispersive delay for polar.2
TFORM19 = '1E      '           /
TUNIT19 = 'SECONDS '           /
TTYPE20 = 'DDISP_2 '           / dispersive delay rate for polar. 2
TFORM20 = '1E      '           /
TUNIT20 = 'SEC/SEC '           /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    2 /
NO_POL  =                    2 /
GSTIA0  =   0.00000000000000000E+00 /
DEGPDY  =   0.00000000000000000E+00 /
RDATE   = '2007-08-23'         /
CDATE   = '2007-08-31'         /
NPOLY   =                    6 /
REVISION=   1.00000000000000000E+00 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
```

```
NAXIS   =                    2 /
NAXIS1  =                   82 /
NAXIS2  =                    5 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   11 /
EXTNAME = 'CALC    '           /
EXTVER  =                    1 /
TTYPE1  = 'TIME    '           / Time of center of interval
TFORM1  = '1D      '           /
TUNIT1  = 'DAYS    '           /
TTYPE2  = 'UT1-UTC '           / Difference between UT1 and UTC
TFORM2  = '1D      '           /
TUNIT2  = 'SECONDS '           /
TTYPE3  = 'IAT-UTC '           / Difference between IAT and UTC
TFORM3  = '1D      '           /
TUNIT3  = 'SECONDS '           /
TTYPE4  = 'A1-IAT  '           / Difference between A1 and IAT
TFORM4  = '1D      '           /
TUNIT4  = 'SECONDS '           /
TTYPE5  = 'UT1 TYPE'           / E=extrapol., P=prelim., F+final
TFORM5  = '1A      '           /
TUNIT5  = '        '           /
TTYPE6  = 'WOBXY   '           / x, y polar offsets
TFORM6  = '2D      '           /
TUNIT6  = 'arcsec  '           /
TTYPE7  = 'WOB TYPE'           / E=extrapol., P=prelim., F+final
TFORM7  = '1A      '           /
TUNIT7  = '        '           /
TTYPE8  = 'DPSI    '           / Nutation in longitude
TFORM8  = '1D      '           /
TUNIT8  = 'rad     '           /
TTYPE9  = 'DDPSI   '           / CT derivative of DPSI
TFORM9  = '1D      '           /
TUNIT9  = 'rad/sec '           /
TTYPE10 = 'DEPS    '           / Nutation in obliquity
TFORM10 = '1D      '           /
TUNIT10 = 'rad     '           /
TTYPE11 = 'DDEPS   '           / CT derivative of DEPS
TFORM11 = '1D      '           /
TUNIT11 = 'rad/sec '           /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    2 /
C_SRVR  = 'kepler  '           /
C_VERSN = '9.1     '           /
A_VERSN = '2.2     '           /
I_VERSN = '0.0     '           /
E_VERSN = '9.1     '           /
ACCELGRV=   9.78031846000000016E+00 /
E-FLAT  =   3.35280999999999985E-03 /
```

```
EARTHRAD=   6.37813700000000000E+06 /
MMSEMS  =   1.23000200000000004E-02 /
EPHEPOC =                 2000 /
ETIDELAG=   0.00000000000000000E+00 /
GAUSS   =   1.72020989499999999E-02 /
GMMOON  =   4.90279750000000000E+12 /
GMSUN   =   1.32712438000000000E+20 /
LOVE_H  =   6.09670000000000023E-01 /
LOVE_L  =   8.51999999999999957E-02 /
PRE_DATA=   5.02909659999999985E+03 /
REL_DATA=   1.00000000000000000E+00 /
TIDALUT1=                    0 /
TSECAU  =   4.99004781999999977E+02 /
U-GRV-CN=   6.67200000000000149E-11 /
VLIGHT  =   2.99792458000000000E+08 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                  168 /
NAXIS2  =                 1060 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   21 /
EXTNAME = 'MODEL_COMPS'        /
EXTVER  =                    1 /
TTYPE1  = 'TIME    '           / Time of start of interval
TFORM1  = '1D      '           /
TUNIT1  = 'DAYS    '           /
TTYPE2  = 'SOURCE_ID'          / source id from sources tbl
TFORM2  = '1J      '           /
TTYPE3  = 'ANTENNA_NO'         / antenna id from antennas tbl
TFORM3  = '1J      '           /
TTYPE4  = 'ARRAY   '           / array id number
TFORM4  = '1J      '           /
TTYPE5  = 'FREQID  '           / freq id from frequency tbl
TFORM5  = '1J      '           /
TTYPE6  = 'ATMOS   '           / atmospheric group delay
TFORM6  = '1D      '           /
TUNIT6  = 'SECONDS '           /
TTYPE7  = 'DATMOS  '           / atmospheric group delay rate
TFORM7  = '1D      '           /
TUNIT7  = 'SEC/SEC '           /
TTYPE8  = 'GDELAY  '           / CALC geometric delay
TFORM8  = '1D      '           /
TUNIT8  = 'SECONDS '           /
TTYPE9  = 'GRATE   '           / CALC geometric delay rate
TFORM9  = '1D      '           /
TUNIT9  = 'SEC/SEC '           /
TTYPE10 = 'CLOCK_1 '           / electronic delay
TFORM10 = '1D      '           /
TUNIT10 = 'SECONDS '           /
TTYPE11 = 'DCLOCK_1'           / electronic delay rate
TFORM11 = '1D      '           /
TUNIT11 = 'SEC/SEC '           /
TTYPE12 = 'LO_OFFSET_1'        / station lo_offset for polar. 1
TFORM12 = '4E      '           /
```

```
TUNIT12 = 'HZ      '           /
TTYPE13 = 'DLO_OFFSET_1'       / station lo_offset rate for polar. 1
TFORM13 = '4E      '           /
TUNIT13 = 'HZ/SEC  '           /
TTYPE14 = 'DISP_1  '           / dispersive delay
TFORM14 = '1E      '           /
TUNIT14 = 'SECONDS '           /
TTYPE15 = 'DDISP_1 '           / dispersive delay rate
TFORM15 = '1E      '           /
TUNIT15 = 'SEC/SEC '           /
TTYPE16 = 'CLOCK_2 '           / electronic delay
TFORM16 = '1D      '           /
TUNIT16 = 'SECONDS '           /
TTYPE17 = 'DCLOCK_2'           / electronic delay rate
TFORM17 = '1D      '           /
TUNIT17 = 'SEC/SEC '           /
TTYPE18 = 'LO_OFFSET_2'        / station lo_offset for polar. 2
TFORM18 = '4E      '           /
TUNIT18 = 'HZ      '           /
TTYPE19 = 'DLO_OFFSET_2'       / station lo_offset rate for polar. 2
TFORM19 = '4E      '           /
TUNIT19 = 'HZ/SEC  '           /
TTYPE20 = 'DISP_2  '           / dispersive delay for polar 2
TFORM20 = '1E      '           /
TUNIT20 = 'SECONDS '           /
TTYPE21 = 'DDISP_2 '           / dispersive delay rate for polar 2
TFORM21 = '1E      '           /
TUNIT21 = 'SEC/SEC '           /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
NO_POL  =                    2 /
FFT_SIZE=                  256 /
OVERSAMP=                    0 /
ZERO_PAD=                    0 /
FFT_TWID=                    1 / Version of FFT twiddle table used
TAPER_FN= 'UNIFORM '           /
DELTAT=              0.0013889 / interval days (added by EWG)
TABREV  =                    1 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                   72 /
NAXIS2  =                90240 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   15 /
EXTNAME = 'TAPE_STATISTICS'    /
EXTVER  =                    1 /
TTYPE1  = 'TIME    '           / time of center of interval
```

```
TFORM1  = '1D      '           /
TUNIT1  = 'DAYS    '           /
TTYPE2  = 'VSN     '           / VSN id
TFORM2  = '8A      '           /
TTYPE3  = 'ANTENNA_NO'         / antenna id from antennas tbl
TFORM3  = '1J      '           /
TTYPE4  = 'ANTENNA_NAME'       / antenna name
TFORM4  = '4A      '           /
TTYPE5  = 'REC_NO  '           / recorder number from antenna
TFORM5  = '1J      '           /
TTYPE6  = 'PBD_NO  '           / correlator playback drive
TFORM6  = '1J      '           /
TTYPE7  = 'SPEED   '           / tape speed and direction
TFORM7  = '1D      '           /
TTYPE8  = 'HEAD_POS'           / recorder headstack position
TFORM8  = '1J      '           /
TTYPE9  = 'QUALIFIER'          / 0 = statistics, 1 = out of sync, 2 = idle
TFORM9  = '1J      '           /
TTYPE10 = 'HEAD_NO '           / recorder head number
TFORM10 = '1J      '           /
TTYPE11 = 'PARITY  '           / parity error count
TFORM11 = '1J      '           /
TTYPE12 = 'HEADER  '           / header error count
TFORM12 = '1J      '           /
TTYPE13 = 'RESYNC  '           / resync count
TFORM13 = '1J      '           /
TTYPE14 = 'INVALID '           / invalid frame count
TFORM14 = '1J      '           /
TTYPE15 = 'FRAME   '           / frame count for above
TFORM15 = '1J      '           /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    2 /
FILE_MJD=   5.43439079631558634E+04 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                   72 /
NAXIS2  =                    0 / [number of rows is initially zero]
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                    4 /
EXTNAME = 'SPACECRAFT_ORBIT'   /
EXTVER  =                    1 /
TTYPE1  = 'SPACECR '           / spacecraft name
TFORM1  = '16A     '           /
TTYPE2  = 'TIME    '           / UT time
TFORM2  = '1D      '           /
TUNIT2  = 'DAYS    '           /
```

```
TTYPE3  = 'ORBXYZ  '           / geocentric coordinates
TFORM3  = '3D      '           /
TUNIT3  = 'METERS  '           /
TTYPE4  = 'VELXYZ  '           / velcity vector
TFORM4  = '3D      '           /
TUNIT4  = 'METERS/SEC'         /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    1 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                  112 /
NAXIS2  =                 1058 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   10 /
EXTNAME = 'FLAG    '           /
EXTVER  =                    1 /
TTYPE1  = 'SOURCE_ID'          / source id number from source tbl
TFORM1  = '1J      '           /
TTYPE2  = 'ARRAY   '           / ????
TFORM2  = '1J      '           /
TTYPE3  = 'ANTS    '           / antenna id from antennas tbl
TFORM3  = '2J      '           /
TUNIT3  = '        '           /
TTYPE4  = 'FREQID  '           / freq id number from frequency tbl
TFORM4  = '1J      '           /
TTYPE5  = 'TIMERANG'           / time flag condition begins, ends
TFORM5  = '2E      '           /
TUNIT5  = 'DAYS    '           /
TTYPE6  = 'BANDS   '           / true if the baseband is bad
TFORM6  = '4J      '           /
TTYPE7  = 'CHANS   '           / channel range to be flagged
TFORM7  = '2J      '           /
TTYPE8  = 'PFLAGS  '           / flag array for polarization
TFORM8  = '4J      '           /
TTYPE9  = 'REASON  '           / reason for data to be flagged bad
TFORM9  = '40A     '           /
TTYPE10 = 'SEVERITY'           / severity code
TFORM10 = '1J      '           /
OBSCODE = 'BL146   '           / Proposal code
RDATE   = '2007-08-23'         / Reference date
NO_STKD =                    4 / Nmbr stokes
STK_1   =                   -1 / First stokes
NO_BAND =                    4 / Number of basebands
NO_CHAN =                    8 / Number of channels
REF_FREQ=   8.40549000000000000E+09 / Frequency reference
CHAN_BW =   1.00000000000000000E+06 / Channel bandwidth
```

```
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    2 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                   92 /
NAXIS2  =                  398 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   10 /
EXTNAME = 'SYSTEM_TEMPERATURE' /
EXTVER  =                    1 /
TTYPE1  = 'TIME    '           / time of center of interval
TFORM1  = '1D      '           /
TUNIT1  = 'DAYS    '           /
TTYPE2  = 'TIME_INTERVAL'      / time span of datum
TFORM2  = '1E      '           /
TUNIT2  = 'DAYS    '           /
TTYPE3  = 'SOURCE_ID'          / source id number from source tbl
TFORM3  = '1J      '           /
TTYPE4  = 'ANTENNA_NO'         / antenna id from array geom. tbl
TFORM4  = '1J      '           /
TTYPE5  = 'ARRAY   '           / ????
TFORM5  = '1J      '           /
TTYPE6  = 'FREQID  '           / freq id number from frequency tbl
TFORM6  = '1J      '           /
TTYPE7  = 'TSYS_1  '           / system temperature
TFORM7  = '4E      '           /
TUNIT7  = 'K       '           /
TTYPE8  = 'TANT_1  '           / antenna temperature
TFORM8  = '4E      '           /
TUNIT8  = 'K       '           /
TTYPE9  = 'TSYS_2  '           / system temperature
TFORM9  = '4E      '           /
TUNIT9  = 'K       '           /
TTYPE10 = 'TANT_2  '           / antenna temperature
TFORM10 = '4E      '           /
TUNIT10 = 'K       '           /
OBSCODE = 'BL146   '           / Proposal code
RDATE   = '2007-08-23'         / Reference date
NO_STKD =                    4 / Nmbr stokes
STK_1   =                   -1 / First stokes
NO_BAND =                    4 / Number of basebands
NO_CHAN =                    8 / Number of channels
REF_FREQ=   8.40549000000000000E+09 / Frequency reference
CHAN_BW =   1.00000000000000000E+06 / Channel bandwidth
REF_PIXL=   5.31250000000000000E-01 /
NO_POL  =                    2 /
TABREV  =                    1 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                  484 /
NAXIS2  =                  241 /
```

```
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   17 /
EXTNAME = 'PHASE-CAL'          /
EXTVER  =                    1 /
TTYPE1  = 'TIME    '           / time of center of interval
TFORM1  = '1D      '           /
TUNIT1  = 'DAYS    '           /
TTYPE2  = 'TIME_INTERVAL'      / time span of datum
TFORM2  = '1E      '           /
TUNIT2  = 'DAYS    '           /
TTYPE3  = 'SOURCE_ID'          / source id number from source tbl
TFORM3  = '1J      '           /
TTYPE4  = 'ANTENNA_NO'         / antenna id from array geom. tbl
TFORM4  = '1J      '           /
TTYPE5  = 'ARRAY   '           / ????
TFORM5  = '1J      '           /
TTYPE6  = 'FREQID  '           / freq id number from frequency tbl
TFORM6  = '1J      '           /
TTYPE7  = 'CABLE_CAL'          / cable length calibration
TFORM7  = '1D      '           /
TUNIT7  = 'SECONDS '           /
TTYPE8  = 'STATE_1 '           / state counts (4 per baseband)
TFORM8  = '16E     '           /
TTYPE9  = 'PC_FREQ_1'          / Pcal recorded frequency
TFORM9  = '8D      '           /
TUNIT9  = 'Hz      '           /
TTYPE10 = 'PC_REAL_1'          / Pcal real
TFORM10 = '8E      '           /
TTYPE11 = 'PC_IMAG_1'          / Pcal imag
TFORM11 = '8E      '           /
TTYPE12 = 'PC_RATE_1'          / Pcal rate
TFORM12 = '8E      '           /
TTYPE13 = 'STATE_2 '           / state counts (4 per baseband)
TFORM13 = '16E     '           /
TTYPE14 = 'PC_FREQ_2'          / Pcal recorded frequency
TFORM14 = '8D      '           /
TUNIT14 = 'Hz      '           /
TTYPE15 = 'PC_REAL_2'          / Pcal real
TFORM15 = '8E      '           /
TTYPE16 = 'PC_IMAG_2'          / Pcal imag
TFORM16 = '8E      '           /
TTYPE17 = 'PC_RATE_2'          / Pcal rate
TFORM17 = '8E      '           /
OBSCODE = 'BL146   '           / Proposal code
RDATE   = '2007-08-23'         / Reference date
NO_STKD =                    4 / Nmbr stokes
STK_1   =                   -1 / First stokes
NO_BAND =                    4 / Number of basebands
NO_CHAN =                    8 / Number of channels
REF_FREQ=   8.40549000000000000E+09 / Frequency reference
CHAN_BW =   1.00000000000000000E+06 / Channel bandwidth
REF_PIXL=   5.31250000000000000E-01 /
NO_TONES=                    2 /
NO_POL  =                    2 /
TABREV  =                    2 /
END
```

```
XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                   44 / 2 columns empty
NAXIS2  =                   70 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   12 /
EXTNAME = 'WEATHER '           /
EXTVER  =                    1 /
TTYPE1  = 'TIME    '           / time of measurement
TFORM1  = '1D      '           /
TUNIT1  = 'DAYS    '           /
TTYPE2  = 'TIME_INTERVAL'      / time span over which data applies
TFORM2  = '1E      '           /
TUNIT2  = 'DAYS    '           /
TTYPE3  = 'ANTENNA_NO'         / antenna id from antennas tbl
TFORM3  = '1J      '           /
TTYPE4  = 'TEMPERATURE'        / ambient temperature
TFORM4  = '1E      '           /
TUNIT4  = 'CENTIGRADE'         /
TTYPE5  = 'PRESSURE'           / atmospheric pressure
TFORM5  = '1E      '           /
TUNIT5  = 'MILLIBARS'          /
TTYPE6  = 'DEWPOINT'           / dewpoint
TFORM6  = '1E      '           /
TUNIT6  = 'CENTIGRADE'         /
TTYPE7  = 'WIND_VELOCITY'      / wind velocity
TFORM7  = '1E      '           /
TUNIT7  = 'M/SEC   '           /
TTYPE8  = 'WIND_DIRECTION'     / wind direction
TFORM8  = '1E      '           /
TUNIT8  = 'DEGREES '           /
TTYPE9  = 'WIND_GUST'          / wind gusts
TFORM9  = '1E      '           /
TUNIT9  = 'M/SEC   '           /
TTYPE10 = 'PRECIPITATION'      / precipitation since midnight
TFORM10 = '1E      '           /
TUNIT10 = 'CM      '           /
TTYPE11 = 'WVR_H2O '           /
TFORM11 = '0E      '           / note empty column
TUNIT11 = '        '           /
TTYPE12 = 'IONOS_ELECTRON'     /
TFORM12 = '0E      '           / note empty column
TUNIT12 = '        '           /
OBSCODE = 'BL146   '           / Proposal code
RDATE   = '2007-08-23'         / Reference date
NO_STKD =                    4 / Nmbr stokes
STK_1   =                   -1 / First stokes
NO_BAND =                    4 / Number of basebands
NO_CHAN =                    8 / Number of channels
REF_FREQ=   8.40549000000000000E+09 / Frequency reference
CHAN_BW =   1.00000000000000000E+06 / Channel bandwidth
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                   3 /
MAPFUNC = '        '           /
WVR_TYPE= '        '           /
ION_TYPE= '        '           /
```

```
END


XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                  588 /
NAXIS2  =                   10 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   19 /
EXTNAME = 'GAIN_CURVE'         /
EXTVER  =                    1 /
TTYPE1  = 'ANTENNA_NO'         / antenna id from array geom. tbl
TFORM1  = '1J       '          /
TUNIT1  = '         '          /
TTYPE2  = 'ARRAY    '          / ????
TFORM2  = '1J       '          /
TTYPE3  = 'FREQID   '          / freq id number from frequency tbl
TFORM3  = '1J       '          /
TUNIT3  = '         '          /
TTYPE4  = 'TYPE_1   '          / gain curve type
TFORM4  = '4J       '          /
TUNIT4  = '         '          /
TTYPE5  = 'NTERM_1  '          / number of terms
TFORM5  = '4J       '          /
TUNIT5  = '         '          /
TTYPE6  = 'X_TYP_1  '          / abscissa type of plot
TFORM6  = '4J       '          /
TUNIT6  = '         '          /
TTYPE7  = 'Y_TYP_1  '          / second axis of 3d plot
TFORM7  = '4J       '          /
TUNIT7  = '         '          /
TTYPE8  = 'X_VAL_1  '          / For tabulated curves
TFORM8  = '4E       '          /
TUNIT8  = '         '          /
TTYPE9  = 'Y_VAL_1  '          / For tabulated curves
TFORM9  = '24E      '          /
TUNIT9  = '         '          /
TTYPE10 = 'GAIN_1   '          / Gain curve
TFORM10 = '24E      '          /
TUNIT10 = '         '          /
TTYPE11 = 'SENS_1   '          / Sensitivity
TFORM11 = '4E       '          /
TUNIT11 = 'Kelvin/Jy'          /
TTYPE12 = 'TYPE_2   '          / gain curve type
TFORM12 = '4J       '          /
TUNIT12 = '         '          /
TTYPE13 = 'NTERM_2  '          / number of terms
TFORM13 = '4J       '          /
TUNIT13 = '         '          /
TTYPE14 = 'X_TYP_2  '          / abscissa type of plot
TFORM14 = '4J       '          /
TUNIT14 = '         '          /
TTYPE15 = 'Y_TYP_2  '          / second axis of 3d plot
TFORM15 = '4J       '          /
TUNIT15 = '         '          /
TTYPE16 = 'X_VAL_2  '          / For tabulated curves
TFORM16 = '4E       '          /
```

```
TUNIT16 = '        '            /
TTYPE17 = 'Y_VAL_2 '            / For tabulated curves
TFORM17 = '24E     '            /
TUNIT17 = '        '            /
TTYPE18 = 'GAIN_2  '            / Gain curve
TFORM18 = '24E     '            /
TUNIT18 = '        '            /
TTYPE19 = 'SENS_2  '            / Sensitivity
TFORM19 = '4E      '            /
TUNIT19 = 'Kelvin/Jy'           /
OBSCODE = 'BL146   '            / Proposal code
RDATE   = '2007-08-23'          / Reference date
NO_STKD =                    4 / Nmbr stokes
STK_1   =                   -1 / First stokes
NO_BAND =                    4 / Number of basebands
NO_CHAN =                    8 / Number of channels
REF_FREQ=   8.40549000000000000E+09 / Frequency reference
CHAN_BW =   1.00000000000000000E+06 / Channel bandwidth
REF_PIXL=   5.31250000000000000E-01 /
NO_POL  =                    2 /
NO_TABS =                    6 /
TABREV  =                    1 /
END

XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                 1136 /
NAXIS2  =                96843 /
PCOUNT  =                    0 /
GCOUNT  =                    1 /
TFIELDS =                   13 /
EXTNAME = 'UV_DATA '           /
EXTVER  =                    1 /
TTYPE1  = 'UU      '           / u (corrected by EWG)
TFORM1  = '1E      '           /
TUNIT1  = 'SECONDS '           /
TTYPE2  = 'VV      '           / v (corrected by EWG)
TFORM2  = '1E      '           /
TUNIT2  = 'SECONDS '           /
TTYPE3  = 'WW      '           / w (corrected by EWG)
TFORM3  = '1E      '           /
TUNIT3  = 'SECONDS '           /
TTYPE4  = 'DATE    '           / Julian day at 0 hr current day
TFORM4  = '1D      '           /
TUNIT4  = 'DAYS    '           /
TTYPE5  = 'TIME    '           / IAT time
TFORM5  = '1D      '           /
TUNIT5  = 'DAYS    '           /
TTYPE6  = 'BASELINE'           / baseline: ant1*256 + ant2
TFORM6  = '1J      '           /
TTYPE7  = 'FILTER  '           / filter id number
TFORM7  = '1J      '           /
TTYPE8  = 'SOURCE_ID'          / source id number from source tbl
TFORM8  = '1J      '           /
TTYPE9  = 'FREQID  '           / freq id number from frequency tbl
TFORM9  = '1J      '           /
TTYPE10 = 'INTTIM  '           / time span of datum (seconds)
```

```
TFORM10 = '1E      '           /
TTYPE11 = 'WEIGHT  '           / weights proportional to time
TFORM11 = '16E     '           /
TTYPE12 = 'GATEID  '           / gate id from gate model table
TFORM12 = '0J      '           /
TTYPE13 = 'FLUX    '           / data matrix
TFORM13 = '256E    '           /
TUNIT13 = 'UNCALIB '           /
NMATRIX =                    1 /
DATE-OBS= '2007-08-23'         /
TELESCOP= 'VLBA    '           /
OBSERVER= 'GOOFY   '           /
OBSCODE = 'BL146   '           /
RDATE   = '2007-08-23'         /
NO_STKD =                    4 /
STK_1   =                   -1 /
NO_BAND =                    4 /
NO_CHAN =                    8 /
REF_FREQ=   8.40549000000000000E+09 /
CHAN_BW =   1.00000000000000000E+06 /
REF_PIXL=   5.31250000000000000E-01 /
TABREV  =                    2 / ARRAY changed to FILTER
VIS_SCAL=   1.08991348743438721E+00 /
SORT    = 'T*      '           /
MAXIS   =                    6 /
MAXIS1  =                    2 /
CTYPE1  = 'COMPLEX '           /
CDELT1  =   1.00000000000000000E+00 /
CRPIX1  =   1.00000000000000000E+00 /
CRVAL1  =   1.00000000000000000E+00 /
MAXIS2  =                    4 /
CTYPE2  = 'STOKES  '           /
CDELT2  =  -1.00000000000000000E+00 /
CRPIX2  =   1.00000000000000000E+00 /
CRVAL2  =  -1.00000000000000000E+00 /
MAXIS3  =                    8 /
CTYPE3  = 'FREQ    '           /
CDELT3  =   1.00000000000000000E+06 /
CRPIX3  =   5.31250000000000000E-01 /
CRVAL3  =   8.40549000000000000E+09 /
MAXIS4  =                    4 /
CTYPE4  = 'BAND    '           /
CDELT4  =   1.00000000000000000E+00 /
CRPIX4  =   1.00000000000000000E+00 /
CRVAL4  =   1.00000000000000000E+00 /
MAXIS5  =                    1 /
CTYPE5  = 'RA      '           /
CDELT5  =   0.00000000000000000E+00 /
CRPIX5  =   1.00000000000000000E+00 /
CRVAL5  =   0.00000000000000000E+00 /
MAXIS6  =                    1 /
CTYPE6  = 'DEC     '           /
CDELT6  =   0.00000000000000000E+00 /
CRPIX6  =   1.00000000000000000E+00 /
CRVAL6  =   0.00000000000000000E+00 /
TMATX11 =                    T /
END
```